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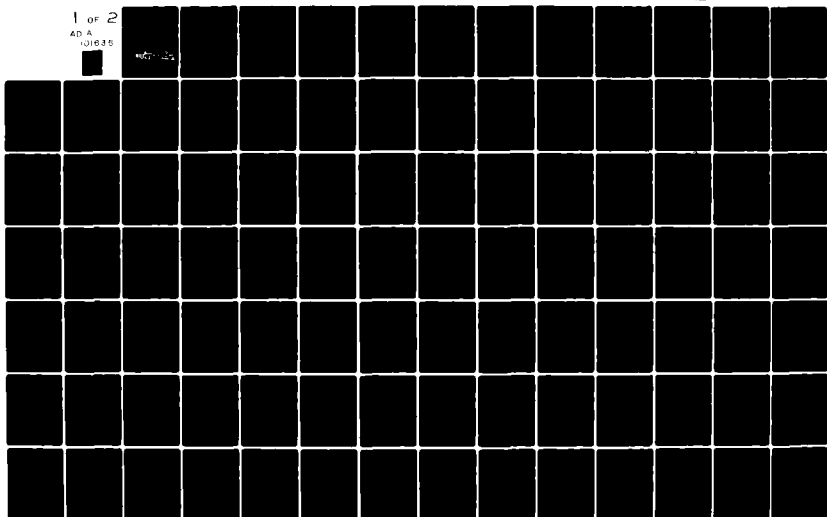
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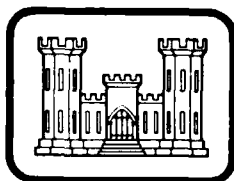
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# DETERIORATION AND REPAIR OF CONCRETE IN THE LOWER MONUMENTAL NAVIGATION LOCK WALL

by

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June 1981

Final Report

Approved For Public Release; Distribution Unlimited

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Prepared for Office, Chief of Engineers, U. S. Army  
Washington, D. C. 20314

Under CWIS 31553

Monitored by Structures Laboratory  
U. S. Army Engineer Waterways Experiment Station  
P. O. Box 631, Vicksburg, Miss. 39180

M. P. SL-81-9

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Miscellaneous Paper SL-81-9 ✓	2. GOVT ACCESSION NO. AD-A107635	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DETERIORATION AND REPAIR OF CONCRETE IN THE LOWER MONUMENTAL NAVIGATION LOCK WALL	5. TYPE OF REPORT & PERIOD COVERED 9 Final report	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Ernest K. Schrader	8. CONTRACT OR GRANT NUMBER(s) 14 WES/MP/SL-81-9	
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer District, Walla Walla Building 602, City-County Airport Walla Walla, Wash. 99362	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS CWIS 31553	
11. CONTROLLING OFFICE NAME AND ADDRESS Office, Chief of Engineers, U. S. Army Washington, D. C. 20314	12. REPORT DATE June 1981	13. NUMBER OF PAGES 121
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) U. S. Army Engineer Waterways Experiment Station Structures Laboratory P. O. Box 631, Vicksburg, Miss. 39180	15. SECURITY CLASS. (of this report) Unclassified	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report)  Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES  Available from National Technical Information Service, Springfield, Va. 22161		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)  Concrete deterioration Locks (Waterways) Lower Monumental Lock and Dam Navigation dams		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) → Deterioration of navigation lock wall concrete due to freezing and thaw- ing is a serious problem which is usually attributed to the ineffectiveness or lack of a proper air-void system in the concrete. Most of the affected locks were constructed many years ago before air-entrained concrete began to be widely used. However, Lower Monumental Lock, one of the largest locks in the world, has only been in service for 10 years yet has serious surface deterioration. (Continued)		

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20. ABSTRACT (Continued)

→ Depending on the extent of concrete deterioration, conventional techniques for repair of deteriorated concrete surfaces normally require the removal of about 1 ft of face concrete, placing anchors and reinforcing steel mat, and replacing the removed concrete with new high-quality air-entrained concrete. This type of repair is very expensive and can put a lock out of service for a long period of time. At Lower Monumental, the cost of conventional repair was estimated to be prohibitive, and the lock could not be taken out of service for more than a matter of weeks. A coating was needed that (a) could be applied in a short period of time, (b) might prevent continued damage from freezing and thawing, and (c) would be permanent under the adverse service conditions.

Six coatings of various portland cement and fine aggregate mixtures were pneumatically applied to a section of the lock wall for evaluation. Each was applied at a thickness of approximately 3/8 in. A conventional dry-mix shotcrete was used as the control material and was compared to fiberglass fiber-reinforced mortar applied by the "spray-up" process with and without latex. ← Air-entraining cement mixtures were also compared to nonair-entraining mixtures.

An accurate account of construction equipment, procedures, and production time was maintained, and "constructability" by these methods was evaluated. Laboratory evaluation included resistance to oils, permeability at various pressures, absorption, air-void size and spacing, resistance to freezing and thawing, tensile and flexural strength, and impact resistance. The latex-modified fiber-reinforced material had essentially no permeability, high impact resistance, and very high strength and suffered no damage due to freezing and thawing. Total coating of the interior lock wall with this mixture was performed in March 1980.

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## PREFACE

This report was prepared by the U. S. Army Engineer District, Walla Walla. The publication of this report was funded as part of Civil Works Investigation Studies (CWIS) Work Unit 31553, "Maintenance and Preservation of Civil Works Structures."

This report discusses surface deterioration and repairs of concrete in the Lower Monumental Lock on the Snake River in Washington. It includes discussion of laboratory studies, testing, construction, and field evaluation of the original concrete and of the various cementitious coatings used for repairs.

Initial laboratory investigations began in 1975. A full-scale field demonstration of the repair procedure was performed in 1979. The complete repair was accomplished under contract in 1980.

The lock is operated and maintained by the Walla Walla District. Colonels Allaire and Thayer were District Engineers during the majority of this work. Mr. Ernest K. Schrader, Foundations and Materials Branch, was principal engineer for the project and wrote this report. Laboratory work was done at the Corps' North Pacific Division Laboratory at Troutdale, Oreg., under the direction of Messrs. Orville Borge, Director, and James Paxton, Concrete Branch Chief.

Director of WES during the preparation of this report was COL N. P. Conover, CE. Technical Director was Mr. F. R. Brown.

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- 1 Lower Snake River Project Map
- 2 Lower Monumental Lock and Dam
- 3 Photograph of Lower Monumental Lock and Dam
- 4 Photographs of the Trial Coating
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CONVERSION FACTORS, INCH-POUND TO METRIC (SI)  
UNITS OF MEASUREMENT

Inch-pound units of measurement used in this report can be converted to metric (SI) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
cubic feet	0.3048	cubic metres
cubic yards	0.764555	cubic metres
feet	0.3048	metres
inches	25.4	millimetres
miles (U. S. statute)	1.609344	kilometres
ounces (mass)	0.028635	kilograms
pounds (force)	4.448222	newtons
pounds (force) per square inch	0.006894757	megapascals
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.018463	kilograms per cubic metre
square feet	0.09290304	square metres

DETERIORATION AND REPAIR OF CONCRETE  
IN THE LOWER MONUMENTAL NAVIGATION LOCK WALL

SECTION I - PROJECT DESCRIPTION

Lower Monumental Lock and Dam is a \$230-million (1961 dollars) project located on the Snake River about 40 miles\* from Pasco, WA (Plates 1 and 2). Initial construction began in 1961 and the project was put in operation in 1970. The dam consists of a concrete gravity structure, a six-bay powerhouse, and earthfill embankments (Plates 2 and 3). It has a total length of 3800 ft and an effective head of 103 ft. Included between the powerhouse and south embankment is a navigation lock for passage of pleasure craft and commercial barges. The lock chamber has clear dimensions of 86 by 675 ft and a lift height of 103 ft.

The lock is one of the links in the inland waterway from the Pacific coast through Portland, OR, to Lewiston, ID, along the Columbia and Snake Rivers. Because there are no alternate waterways or lock, the transportation system stops if the lock is taken out of service for repairs.

The environment at Lower Monumental is harsh from the standpoint of concrete durability. The region does not have extreme winters where the temperature drops below freezing and remains there. Instead, the concrete is exposed to many alternate freezing and thawing cycles. This exposure is exaggerated at the lock where each lockage can cause a cycle when the water is just above freezing and the air temperature is below freezing. Temperature data for each month based on every other year since the project became operational are given in Exhibit 1. The range between highest and lowest temperature goes from 12<sup>0</sup> Fahrenheit to 111<sup>0</sup> Fahrenheit. Cycles of freezing and thawing based on daily ambient

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\* A table of factors for converting inch-pound units of measurement to metric (SI) units is presented on page iv.

temperature changes (a conservative estimate of total freeze-thaw cycles) is also given in Exhibit 1. The average is 64 cycles per year. Lock usage shown in Exhibit 1 indicates about 475 commercial lockages during the months of freezing weather each year. Currently, about 1400 commercial lockages occur each year and an estimated 12,000 commercial lockages have occurred since the project became operational.

## SECTION II - CONCRETE DETERIORATION

Deterioration of concrete in navigation lock walls has caused serious maintenance, aesthetic, operational, and safety problems at a number of structures. Most of these are older structures built 40 or 50 years ago along the Mississippi River system and its tributaries, but Lower Monumental lock is a new structure which has the same problem. It is an irreversible condition for which conventional repairs are expensive. At Lower Monumental safety is of particular concern because of the very high (103-ft) lift. If a loose piece of aggregate fell from the upper portion of the lock onto a pleasure craft or an individual, serious damage, injury, or death could result.

Deterioration of concrete at navigation locks is typically the result of an improper air-void system in the concrete and, consequently, low resistance to damage by freezing and thawing. Repeated saturation of the wall surface due to filling and emptying a lock, coupled with the many cycles of freezing and thawing, progressively cause damage to the mortar portion of the concrete. For two reasons, the extent of freezing and thawing cycling and degree of damage are much worse for a lock chamber surface than would otherwise be the case. First, not only is a source of water always present to provide an approach to critical saturation, but pressure from water in the lock can accelerate the rate and depths of saturation. Second, when the ambient temperature stays below freezing and is not going through damaging freezing and thawing cycles, concrete in the lock chamber may be repeatedly frozen and thawed by alternately being subjected to river water just above freezing and the air temperature below freezing. In a high lock, the freezing point of water absorbed in the concrete can even change due to hydrostatic pressures from filling the lock.

The reason for an improper air-void system usually is that a structure was built many years ago, before the benefits of entrained air were

appreciated, and it simply was not required. At Lower Monumental lock the reasons were different. Aggregates for the concrete were natural materials screened from river deposits. During construction, it was necessary to use an unusually high dosage of air-entraining admixture in order to stay above the acceptable lower limit of required air content. It was checked at the time of batching and before placement. However, analysis of hardened concrete from the lock indicated that the actual air content was less than required and that the concrete had very low resistance to freezing and thawing. Exhibit 2 contains the results of those tests showing an overall average DFE of 49. Exhibit 3 contains results of air content determinations showing only 1.6% average entrained air.

Because job records did not agree with the results of tests on the in-place concrete, leftover aggregates from original construction stockpiles were uncovered and screened to what records showed was used during construction. Air contents immediately after mixing the concrete were checked and found to be acceptable. Workability of the concrete at that time was considered to be good. This represents the condition when slump and air content tests would have been made on the project at the batch plant. The laboratory mixture was then rehandled, allowed to sit for 30 m, and vibrated to simulate hauling and placing. Exhibit 3 contains the results of these tests (NOTE: The data for Mix 386-9 were erroneously typed for Mix 386-18 in the report, page 3, of Exhibit 3, and the data for Mix 386-18 were erroneously typed for Mix 386-9). The workability changed drastically in this 30-m time delay. The mixture lost slump, stiffened, and would "post hole" when vibrated. The total air content for the fraction of the mixture passing the 19.0-mm (3/4-in.) sieve dropped from 6.5 percent to 5.3 percent. Analysis of hardened samples of the concrete showed that this change consisted of a 0.2% increase in entrapped air with a 1.4% decrease in entrained air. Beams made immediately after mixing and after the 30-m delay both had good resistance to freezing and thawing, with a DFE of 87 for the delayed material compared to 90 for the specimens made immediately after mixing.

However, the amount of surface relief and the percent weight loss was about 60% greater for the beams cast after the 30-m delay. These results indicate that during construction, the air content immediately after mixing was probably acceptable, but by the time the mixture had been rehailed, placed, and heavily vibrated, the entrained air had dropped significantly.

The premature stiffening problem was attributed to natural fine aggregate in the river-deposited aggregate source. A petrographic analysis of it is included in Exhibit 3. The material is essentially basalt with some granite, quartz, and feldspar and about 6% of it consists of porous, absorptive, or friable basalt particles and silty caliche. Some of the basalt contained montmorillonite clay which is suspected of being the cause of the stiffening problem. It was not a dust coating of clay that could be washed off, but was contained within the smaller particles. For subsequent concrete operations after the lock and south shore work was completed, all fine aggregate was manufactured from material retained on the 9.5-mm (3/8-in.) sieve. This eliminated the stiffening problem and resulted in concrete that has held up very well to natural weathering.

A complete explanation of factors that affected the air-void system and what the phenomenon was that was responsible for requiring a very high initial air-entraining admixture dosage is not available. There may have been a chemical or physical breakdown that occurred in the mixture. The available explanation is that the fine aggregate, possibly because it contained montmorillonite, caused severe stiffening of the mixture. This may have chemically affected the air-entraining capacity of the concrete. It did reduce the amount of available water. Experience has shown that for very dry, no-slump mixtures, it is difficult or impossible to obtain an effective air-void system. The very stiff condition of the mixture necessitated considerably more vibration during placement than is normal, and this may also have contributed to a reduction in effective entrained air, although it should not have done so.

SECTION III - REPAIR METHOD POSSIBILITIES  
AND INITIAL LABORATORY STUDIES

Concrete deterioration at Lower Monumental was evident after several years of operation. It progressed through the next few years to the point where it became obvious that repairs would be necessary. The lower areas of the lock chamber had the worst damage with 75-mm to 150-mm (3- to 6-in.) aggregate fully exposed after about eight years of service. In addition to repairing the badly damaged areas, a treatment was needed that would prevent further deterioration of those areas not yet damaged to the point of needing repair.

A conservative approach to repairs would have followed a procedure similar to that used or proposed at other navigation locks such as those in the Ohio and Mississippi River systems. This consists of removing about the first foot of face concrete and replacing it with high-quality air-entrained new concrete conventionally reinforced with steel and anchored to the existing mass with grouted bars. The cost of doing this at low head structures would be very high and the repair schedule requires long periods of time for construction. Even worse is the economic impact caused by stopping or slowing the flow of barged goods during repairs. At Lower Monumental this approach to repairs would be exorbitant from the standpoint of cost, time, and shipping.

The Lower Monumental lock is one of the largest in the world with a lift of 103 ft and draft of about 20 ft. The possibility of providing a floating cofferdam or caisson which would span one monolith at a time and seal to the lock wall to allow men to work inside of it while the lock remained in use was investigated. This would have allowed repairs to be made without taking the lock out of service. Because only one monolith could be worked on at a time, the project would stretch out for many years. The caisson would be supported by only one monolith on each side of the monoliths being repaired. A hazardous overload would

be transmitted to them by hydrostatic pressure against the caisson. The caisson would have to be designed to essentially be a floating steel dam about 150 ft high, spanning about a 60-ft width, with a daily fluctuating reservoir of 103 ft. The design would have called for an expensive and massive steel structure too heavy and unwieldy to handle in the lock. It would have had to seal against the deteriorated lock wall and been deeply anchored. Because the caisson would protrude out into the lock chamber, the barges which typically go through as double-wide rafts would have to split into single-wide rafts and make two trips. For safety reasons, personnel working within the caisson would probably be required to evacuate during each lockage. In summary, this concept for repair was not feasible from the standpoints of construction time, design, practicality, and safety.

If a conventional approach taking more than a few weeks' lock outage period for construction were used, the only acceptable way to make the repairs would be to provide transfer facilities around the lock. This would have cost an estimated \$13 million, and it would not have allowed the passage of pleasure craft. An additional cost of about \$250,000 to the Government to maintain the lock in a long-term unwatered condition would have been incurred. The estimated construction cost for conventional "remove and replace" repairs at Lower Monumental was \$13 million in addition to the \$13 million required for transfer facilities, for a \$26 million total cost.

A faster and more economical method of repair and prevention of further deterioration of the lock walls was needed. If, after proper surface preparation, a protective shotcrete coating could be applied to the existing wall, large savings in time and material would result. Any build-out would have to be minimal so that the effective lock width would not be reduced. Areas of the structure where severe deterioration and spalling occurred to depths ranging from several inches to several feet would first be filled with concrete, epoxy mortar, shotcrete or other patching material. The surface coating would then be applied over



the patch. Smaller patches not mechanically anchored would be held in place by bond and by the strength of the coating covering them. A program was undertaken to evaluate six different variations of pneumatically applied mortar coatings. In order to be successful, the coating would have to cure rapidly, bond to the existing wall, be resistant to wetting and drying and freezing and thawing cycles, have dimensional stability, and minimal shrinkage due to moisture and temperature changes, prevent the penetration of water through it even at heads of 100 ft while still being able to breathe or relieve vapor pressure when the lock is empty, be resistant to the impact of barges, have acceptable appearance, be able to be applied at temperatures between 30<sup>0</sup> and 90<sup>0</sup> Fahrenheit on a surface that would be near a saturated surface dry condition, and be practical enough to apply in the field at a production rate of about 10,000 ft<sup>2</sup> per day. A material meeting these prerequisites was not located.

The most promising idea was to apply a shotcrete that would contain modifiers which could enhance its qualities. The addition of fibers could add toughness, resilience, impact resistance, strain capacity, and other desirable properties. Impermeability, bond, rapid curing, and minimal shrinkage could be provided by a latex modifier. Portions of concrete from the lock were removed, coated with a 3/8-in.-thick fiber-glass fiber-reinforced latex-modified mortar, and tested to see if this type of coating did, in fact, have potential for repair of the entire lock. A special test (Exhibit 4) was devised to simulate actual lockage conditions during freezing and thawing cycles. The coated concrete specimen is clamped in a jig that seals a ponding area over the coating. Water is introduced into this reservoir and air pressure is applied to develop hydrostatic pressures similar to those exerted against the lock wall during a lockage. From these tests, pressures equivalent to heads of 0, 25, 50, 75, and 100 ft were used. One beam was subjected to a standard unpressurized rapid freezing and thawing test. After each thawing the test specimen surface was flooded and subjected to the specified pressure simulating a lockage. That pressure was maintained for the

duration of a lockage. The pressure was then released to simulate emptying the lock and the specimen was refrozen. After freezing, it was thawed and the cycle was repeated.

At first the results were disappointing (Exhibit 4). Resistance to freezing and thawing ranged from poor to excellent. But, investigation showed that the mortar coating contained latex and had inadvertently not been allowed to air dry (proper cure for a latex-modified mortar) before being tested. This resulted in the poor resistance to freezing and thawing. Because the test specimens failed from the coating surface down, the coating did protect the base concrete from freezing and thawing damage. It was concluded that the system would work if the coating itself did not deteriorate. It was also thought that excellent freezing and thawing resistance could be achieved if the coating were allowed to air dry before being tested. The 3/8-in-thick mortar coating was remade, both with and without latex. Samples of the coating were then subjected to standard rapid freezing and thawing testing. The results (Exhibit 4) confirmed what was expected. The mortar made with fiberglass fibers but no latex failed, but the ones which contained fiberglass fibers and latex showed no damage. Other material properties were also very favorable. The coating was very tough; it handled well, and it had very high ductility.

## SECTION IV - FIELD DEMONSTRATION

### MIXTURE PROPORTIONS

The next steps in evaluation of the specialized shotcrete method of repair and protection were to demonstrate its field practicality, thoroughly test the material properties of field-cast panels, and observe the field performance after a year's exposure to actual operational conditions. A field test was performed on the lock wall by a contractor under fixed bid in 1979. The test section served as a demonstration area allowing comparative evaluation of the performance of coatings without latex and fiber, without latex but with fiber, and with both latex and fiber.

The question had also been raised as to whether a pneumatically applied mortar coating by itself would have sufficient resistance to freezing and thawing if it contained entrained air. A search was made to find out if and how entrained air had been reliably and effectively introduced into pneumatically applied mortars. The results showed that this had been attempted, but was always unsuccessful in both the wet and dry mix process. In some instances oral reports were received that this had been successfully done but when checked further there never was an analysis to check the actual air content, bubble size, bubble spacing, or actual resistance to freezing and thawing in critically saturated conditions. It seemed possible that by using air-entraining cement, an effective air-void system could be realized. This variable was therefore included in the field trial mixtures and the follow-up laboratory testing. The six resulting trial mixtures based on one-cubic-yard batches are shown in Table I.

The mixtures containing fibers required a very high cement factor in order to coat all of the fiber surface area with paste. Each factor is composed of over 100 fine filaments. If this high cement factor were

TABLE I  
FIELD TRIAL MIXTURES

Mixture	Application Procedure	Cement Content, lb	Cement Type	Latex	Fibers	Fine Aggregate, lb	Water-reducing Admixture, oz	Water, lb
1.	Dry Gun	680	III	None	None	2745	None	(5)
2.	Dry Gun	680	I-A	None	None	2745	None	(5)
3.	Wet Spray-up (1)	1810	I	None	123 lb. (3)	905	75 (4)	663
4.	Wet Spray-up (1)	1810	I-A	None	123 lb. (3)	905	75 (4)	663
5.	Wet Spray-up (1)	1720	I	520 lb. (2)	117 lb. (3)	860	75 (4)	172
6.	Wet Spray-up (1)	1720	I-A	520 lb. (2)	117 lb. (3)	860	75 (4)	172

NOTES:

- (1) The wet spray-up process uses a low-pressure wet gun and adds the fibers by chopping and blowing them from a separate gun at the nozzle.
- (2) Latex contained 48% solids. An anti-foam agent was added to all latex mixtures at the rate of 2 lb per 100 lb of latex emulsion.
- (3) Fibers were alkali-resistant glass fibers cut from continuous roving into 4-in.-long strands.
- (4) WRA was a proprietary product meeting ASTM C 494, Type A.
- (5) Actual water content cannot be determined. The driest practical consistency was used.

used for conventional shotcrete, failure of the material due to shrinkage and volume instability would have been expected. In the glass-fiber mixture, the fiber composite provides high strength and strain capacity needed so that shrinkage, cracking, and failure are eliminated or minimized. Hence, a marked variation in cement factor between the trial mixtures was used.

Typical glass fiber mixtures use fiber contents about double the amounts used in the trials. They also use fibers on the order of 1/2 to 1 in. long instead of 4 in. long. For the lock application it was considered unnecessary to have such a high fiber concentration. It was also thought that the longer fiber length and expected lower water-cement ratio would help compensate for loss of material properties resulting from less fiber, while improving dimensional stability under thermal and humidity changes.

Because of the high cement content and method of application, water-cement ratios for the glass fiber mixture without latex were only about 0.36. Because the latex acts as a fluidifier, the effective water-cement ratio for it was only 0.26 (which includes water contained in the latex solution). The latex solids were about 15 percent of the cement weight. These low water-cement ratios were one more reason why the very rich mixtures did not exhibit a problem with shrinkage and dimensional stability.

It should be pointed out that the saran-based latex used was selected because it had exhibited the best initial laboratory strengths and was only slightly more expensive than other polymer modifiers. However, the improvements over a styrene butadiene latex were not very great. If the latex were to be used over steel, with steel fibers, or over a reinforced concrete section with little cover, another latex would have been selected, since the one selected contains chlorides which might result in attack on the steel and damage to the concrete.

## APPLICATION

The navigation lock was built with standard construction with each wall being composed of 16 monoliths cast in place next to each other. A vertical joint separates each monolith from the next. Concrete for each monolith was placed in 5-ft-high lifts. The lock chamber face of monolith 9 had various degrees of surface deterioration ranging from minimal at the top to severe at the bottom. It was divided into six equal 10-ft-wide strips running from the top of the lock down to tailwater. Each strip was coated with one of the trial mixture proportions.

The first, and perhaps most important step, was preparation of the existing surface. Contract specifications, as stated below, were clear with regard to what was to be accomplished during the surface preparation phase:

"Prior to applying any of the shotcrete coatings, the surface shall be prepared by removing all loose, unsound, and friable material and by removing all surface contaminants such as dust, silt, old curing compound, organic growth, etc. The purpose of applying the coatings is to prevent continued deterioration of the mortar portion of the concrete. Due to deterioration that has occurred to date, much of the mortar is very poor, crumbly, and friable. All of this unsound material shall be completely removed prior to application of coating. Any cleaning procedure that safely and thoroughly performs this cleaning without undercutting exposed aggregate will be acceptable. However, the procedure used will be subject to the approval of the Contracting Officer after field demonstration. Some possible cleaning procedures are high-pressure waterjets, air-water cutting, sandblasting, mechanical brushes, or a combination of these techniques...."

Unfortunately, the surface preparation actually provided was less than desired. A water wash with questionable pressure was used for cleanup. In some areas this worked satisfactorily, but in other areas the surface afterward had loose friable mortar between large aggregate particles which could easily be removed by hand or with a screwdriver.

As unfortunately is the case in many construction projects, contract administration and scheduling problems did not permit proper clean-up of all areas prior to application of the new materials. The effects of this will be discussed later. Aside from evaluation of the various mixtures used, the project served well as a demonstration of the importance of obtaining an acceptable surface upon which to apply any shotcrete.

In all of the mixtures, materials were batched and blended at the top of the lock and were then brought to the work platform at the application location. Mixtures 1, 3, and 4 were applied from a hanging platform of limited width which congested working conditions and did not allow the nozzleman to follow good practice. Mixtures 2, 5, and 6 were applied from a much larger floating barge.

The conventional dry-mix shotcrete used a typical concrete sand. The thickness was built out in a single layer. Following application of the mixture the contractor applied a cement-rich "flash coat" as his standard practice. Unfortunately, in his eagerness to do a good job, the contractor over-built the thickness and added the flash coat, neither of which was desired. This made comparative evaluation and some of the information desired on thinner coatings more difficult, or impossible to attain. The work crew consisted of six men. Three of the men handled mixing of the cement and sand; one man was at the nozzle, and one man checked the depth of the coating. It took 6 to 8 h to complete the 10-ft-wide, 115-ft-high strips. Rebound was estimated at 15 to 17% by comparing a visual determination of the volume of rebound collected to the volume of material applied. Shooting was done with an experienced crew, but because the hanging scaffold from which the nozzleman worked was only a few feet wide and close to the wall, it was impossible to shoot directly at the wall without being too close (Plate 4).

The glass-fiber-reinforced materials were applied using the standard "spray-up" process which applies a wet mixture at low pressure,

while the fiberglass fibers are chopped and blown against the surface simultaneously with the mortar. The thickness of material applied was only about 1/8-in. per pass and the surface was rolled with what looks like a serrated paint roller between passes. This pressed the glass fibers into close contact with the mortar. A mat of material resulted which could actually be lifted off in sheets, but which also would sag if too much weight was added too fast.

Because the spray-up process has historically used a fine sand for the aggregate (usually 20/30 pre-bagged sand), the Government contracting Officer agreed to the contractor's request to switch from bulk concrete sand to the pre-bagged finer material. At the end of the job, one test panel was also made for laboratory evaluation with the coarser specified sand. This mixture turned out to work well in the spray-up equipment, had less tendency to sag, and gave the best results in all laboratory tests.

Problems were encountered by one of the contractor's less experienced crews when they began spraying the latex-modified mortar under ambient temperatures of 80<sup>0</sup> F and higher. The material would thicken or develop lumps and plug the equipment. The second work crew had no difficulty with the material, but they were more experienced, used a conventional mortar mixer rather than the "high-shear" mixer, used the minimum hose lengths necessary, and followed close quality control procedures (accurate weighing of batches, pre-mixing the latex solution, use of the flow cone to control workability, careful measurement of the antifoaming agent, etc.). Instead of working from the hanging scaffold, this crew worked from a floating platform with adequate room (Plate 4). As work progressed from the top down, the platform was lowered about 5 ft at a time by slowly emptying the navigation lock. The newly exposed surface which had previously been prepared by removing loose materials was blown dry (SSD) just prior to applying the coatings. Including the time required for all of the incremental lowerings of the lock and for blowing



the surface dry, the crew was able to achieve an overall production rate of over 30 square yards per hour. The work crew consisted of six men. Rebound was estimated less than five percent.

#### EVALUATION

Evaluation of the various mixtures and application procedures consisted of three basic phases: (1) determining the practicality and speed of application of the coatings using construction crews under true field conditions; (2) extensive laboratory evaluation of test panels made and cured in the field; and (3) evaluation of physical performance of the in-place material after one full year of service.

The field applications showed that with experienced crews and proper planning, any of the coating materials could be applied at a reasonable rate under difficult field conditions. If the width of the test panel sections had been greater, the rates of application would have been much greater. The field work also showed that air-entraining cement could be used in any of the mixtures, but that the benefits, as discussed below, are doubtful. From a practical standpoint, the demonstration showed that the latex mixtures had a natural advantage over the conventional mixtures because their use permits a drying period instead of moist cure after application. Good moist curing or properly applied and protected curing compound is typically difficult to obtain in the field, especially on a job like this one where men are working below and adjacent to a 100-ft-high previously applied surface.

Field cast specimens not against rigid plywood boards were removed from the board and trimmed to a thickness of 5/16-in. for testing so that they would all be of the same thickness. This allowed more accurate comparison of data and duplicated the design, thickness for future work. The tabulated results of laboratory tests are given in Tables II-a and II-b.

TABLE IIa  
RESULTS OF LABORATORY TESTING STUDIES

Mix	Unit Weight lb/ft <sup>3</sup>	Absorption %	Flexural Strength psi	Tensile Strength psi	Impact Resistance		Air Content		Freeze/Thaw	
					1st Crack blows	Failure blows	Smaller than 1 mm %	Total %	Cycles	Weight Loss %
1	148	9	890	225	1	1	1.6	2.8	196	31
2	146	9.6	770	25	1	1	4.0	5.1	142	40
3	144	10	2234	861	87	194	1.2	1.8	276 9/	37 9/
4	140	13	3053	1112	88	137	1.1	2.2	276 10/	26 10/
5 1/	133	10	3000	1110	None 6/	350 6/	9.0 7/	9.2 7/	345 8/	2
5 2/	142	10	2770	780	445	500 5/	1.7	1.8	345 8/	1
5 3/	141	10	3250	1580	None 6/	500 5/	2.9	3.1	345 8/	0
6	139	10	2750	1140	125 4/	170 4/	2.3	3.0	345 8/	1

1/ Applied by less-experienced spray-up crew.

2/ Applied by more-experienced spray-up crew.

3/ Conventional concrete sand used for aggregate in lieu of fine bagged sand.

4/ Only one sample tested: sample appeared to have a flaw that led to early failure.

5/ Test was stopped at 500 blows for practical reasons. No evidence of failure.

6/ No cracks. The steel impact ball pulverized a hole through the test specimen.

7/ No WRA used.

8/ Test was stopped for practical reasons at 345 cycles.

9/ Individual sample test results ranged from 100% weight loss @ 44 cycles to 9% weight loss @ 345 cycles.

10/ Individual sample test results ranged from 42% weight loss @ 68 cycles to 8% weight loss @ 345 cycles.

TABLE IIB  
RESULTS OF LABORATORY TESTING STUDIES

Mix	Cycles	Freezing and Thawing; Wetting and Drying Weight Loss %	Kerosene Soak Weight Change %	Deflection <sup>12/</sup>		Coeff of Permeability ft/min/ft head x 10 <sup>-9</sup> head, ft			Flow Through Material ft <sup>3</sup> /ft <sup>2</sup> - day x 10 <sup>-3</sup> head, ft		
				Ultimate Load lb	Defl in	Failure Load lb	Defl in		5	50	100
1	60	2	0	14/	14/	14/	14/	19	9,200	18,400	4 24,500 73,600
2	60	1.8	+1	770	0.035	14/	14/	2.4	0.6	8,000 <sup>13/</sup>	0.5 1.7 32,000 <sup>13/</sup>
3	60	1.8	+1	1640	0.25	14/	14/	85 <sup>11/</sup>	177 <sup>11/</sup>	46 <sup>11/</sup>	22 <sup>11/</sup> 49 <sup>11/</sup> 114 <sup>11/</sup>
4	60	2.7	+1	14/	14/	14/	14/	6	38 <sup>11/</sup>	22 <sup>11/</sup>	1 105 <sup>11/</sup> 97 <sup>11/</sup>
5 <sup>1/</sup>	60	3.0	+1	14/	14/	14/	14/	1	2	1	0 5 0
5 <sup>2/</sup>	60	3.9	+1	2630	0.42	2300	0.56	3	1	1	1 3 5
5 <sup>3/</sup>	60	0.0	+1	2565	0.36	1160	0.65	0	0	0	0 1 1
5 <sup>4/</sup>	14/	14/	+1	14/	14/	14/	14/	2	4	1	1 12 3

4-9

- 1/ Applied by less-experienced spray-up crew.
- 2/ Applied by more-experienced spray-up crew.
- 3/ Conventional concrete sand used for aggregate in lieu of fine bagged sand.
- 4/ Only one sample tested: sample appeared to have a flaw that led to early failure.
- 5/ Test was stopped at 500 blows for practical reasons. No evidence of failure.
- 6/ No cracks. The steel impact ball pulverized a hole through the test specimen.
- 7/ No WRA used.
- 8/ Test was stopped for practical reasons at 345 cycles.
- 9/ Individual sample test results ranged from 100% weight loss @ 44 cycles to 9% weight loss @ 345 cycles.
- 10/ Individual sample test results ranged from 42% weight loss @ 68 cycles to 8% weight loss @ 345 cycles.
- 11/ Individual sample test results varied considerably.
- 12/ Used standard-size flexural panels 2-1/2 in. x 10 in. x 5/16 in.
- 13/ Sample probably cracked. Data does not correlate with test results at 5 ft. and 50 ft. of head.
- 14/ No available data.

Type 1A cement was used on each of the three basic formulations (no latex-no fiber, no latex-with fiber, with latex-with (fiber) to see if controllable and effective air entrainment could be accomplished. It was checked "as shot" in the wet-mix process as it came from the nozzle. This could not be done for the dry-mix process because of the basic equipment and process. A microscopic examination was later made from samples of each mixture sawn from all of the hardened field coatings after cure. The only mixture which had sufficient effective air bubbles (less than 1-mm in size) to provide some resistance to freezing and thawing was one of the batches made with latex and fibers. However, this one test result is suspicious. It does not agree with the results of other batches made with the same mixture proportions and may not have had the correct admixtures. Also, the resistance to freezing and thawing obtained with this material probably should be attributed to the impermeability provided by the latex. The results of the rapid freezing and thawing test on hardened material samples varied considerably for different samples of some of the same mixtures. However, the data do positively show that latex mixtures without entrained air can give extremely good resistance to damage by freezing and thawing.

Alternate wetting and drying and freezing and thawing cycle testing gave results similar to the rapid freezing and thawing tests. Wetting was done by soaking the samples in water for 6 h after drying them for 6 h at 200° F.

Soaking the samples in petroleum (kerosene) had no significant effect.

Specialized tests of permeability and flow were performed to determine if the coatings could effectively prevent the penetration of water under various pressure heads simulating the water depths of the lock. These determinations were made by maintaining a constant head of 5, 50, and 100 ft against field-cast test specimen. The spray-up materials,

with and without latex, performed well. Conventional shotcrete performed very poorly. The latex mixtures with fibers had essentially no flow or permeability, regardless of head.

Unit weights of the different mixtures varied, but, in general, conventional shotcrete had the greatest unit weight, and the glass-fiber spray-up materials had unit weights of about 5% less.

Absorption for the conventional shotcrete was slightly less than that of the higher cement content spray-up coatings. It is expected that if fiberglass fibers were not used in the spray-up mixtures, the absorptions would have been much less. Fiber filaments that are exposed probably tend to act like a wick, absorbing some moisture.

Flexural strengths were determined on the thin coatings, using a specimen 2-1/2 in. wide and 12 in. long. A 10-in. simple span with third-point loading was used. Test results ranged from typical values for conventional shotcrete (890-psi average), to very high strengths for the spray-up materials (3250-psi maximum). During testing the spray-up specimens deflected as much as 3/4 in. without breaking apart.

Direct tensile strengths were also run on thin sections. Results ranged from 225 psi for conventional shotcrete to 1580 psi for spray-up material with latex.

Impact tests were performed using the procedure recommended by ACI Committee 544.<sup>1)</sup> Basically, this test consists of placing a hardened steel ball on top of a 6-in.-diameter disk of the test material, and impacting the ball with a standard 10-lb drop hammer, falling 18 in. The number of blows required to crack the test specimen and the number of blows required to spread the cracks or separate the test specimen were

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1) ACI Committee 544, "Measurement of Properties of Fiber-Reinforced Concrete," ACI Journal, July 1978.

recorded. The conventional shotcrete cracked and separated at one blow of the test apparatus. The spray-up materials with fiber typically required nearly a hundred blows to crack, and many more blows to separate the crack. The glass fiber mixtures with latex that were applied by the more experienced crew never failed.

After a year of being in service, the condition of the various coating materials on the lock wall were closely inspected. Cores were taken in typically good and poor areas of bond for each type of coating. Plate 4 contains a photograph of typical cores. Following are observations of the condition of the field coatings after one year of service. Although only one year of service had been experienced, the environment in the Lower Monumental area subjected the coating to a thorough test. From field performance, coupled with the lab data, positive conclusions can be made.

Mixture 1: Conventional Shotcrete, Type III Cement. Hollow (debonded) areas were present on most lift sections. The sizes of the debonded areas varied considerably, ranging from a few inches in diameter to nearly the entire lift section. A number of fine cracks were present. Although debonded areas and fine cracks were present, the coating surface itself was generally sound, with essentially no change in appearance (with the exception of fine cracks) from the previous summer.

Mixture 2: Conventional Shotcrete, Type IA Cement. The fine cracks evident here did not appear to be as numerous as in Mixture 1. Also there appeared to be fewer hollow areas as compared to Mixture 1. In this section, a large crack in the monolith was noted during application of the coating. This crack reflected through the coating as one tight crack, with no spalling around it.

Mixture 3: Glass-Fiber-Reinforced Shotcrete, Type I Cement. No fine cracks were evident in this section, and very few debonded areas were present. It should be noted that the preparation of the surfaces

prior to application of coatings the previous summer was observed to be better on sections where Mixtures 3 and 4 were applied, as compared to the other four sections. The observations after one year of field service help to confirm the importance of good surface preparation. The surface of this coating (and that of Mixture 4) showed essentially no change in appearance from the previous summer.

Mixture 4: Glass-Fiber-Reinforced Shotcrete, Type IA Cement. A few fine cracks were noted in only one area. The overall percentage of debonded areas on this section was very low.

Mixture 5: Shotcrete Containing Glass Fibers and Latex, Type I Cement. No fine cracks were evident in this section. No hollow (debonded) areas were evident on the upper lifts. However, some of the lower lift sections were almost completely debonded. After one year of field service, this section (and that coated with Mixture 6) were not as good with respect to bonding to the substrate, as were the sections with glass fibers alone. However, this is attributed entirely to differences in preparation of the surfaces prior to coating.

Mixture 6: Shotcrete Containing Glass Fibers and Latex, Type IA Cement. No fine cracks were observed in this section. No debonded areas were evident on the upper lifts, but numerous hollow areas were present in lower lift sections, with some sections having completely peeled-off in large sheets. However, immediately next to some of the peeled-off areas, the bond of the coating to the substrate was excellent. As with all other sections, the surfaces of sections coated with Mixtures 5 and 6 showed essentially no change in appearance from the previous summer.

Results of Tests on Core Samples: Visual examinations of cores indicated that hollow sounding areas were, in fact, delaminated, and the anticipated well-bonded zones were found to be sound. These observations confirmed that the debonding failures were caused by improper surface

preparation. The coatings in such instances were found to be bonded to the mortar from the original (unsound) surface, but the weak surface mortar had peeled away from the rest of the concrete, thereby causing the failure (Plate 4).

#### RECOMMENDATIONS AND CONCLUSIONS

Based on laboratory tests and field trials, the following conclusions and recommendations were made in 1979.

Coating systems, such as the fiber-reinforced-latex-modified system should be extremely effective in terms of time and cost savings when compared to the alternative of removing perhaps 1-1/2 ft of lock wall concrete, placing anchor bars into drilled holes, and replacing the concrete with new concrete. Based on combined field and laboratory evaluations, a contract should be issued to coat the deteriorated lock wall surface at Lower Monumental, during a three-week period, with a thin sprayed-on fiberglass fiber-reinforced-latex-modified coating.

Laboratory and field evaluation of sample panels indicated that overall the best performance can be achieved by a combination of glass fibers and latex, followed in order by glass fibers alone and by conventional shotcrete. The superiority of the latex mix is especially apparent in the permeability, flow, and freeze-thaw tests. These also were the most important tests for the lock wall use of the material.

Proper surface preparations are absolutely essential prior to applying and coating.

Air-entraining cement did not produce adequate entrained air in any of the mixtures used, regardless of mixer type and regardless of whether the wet-mix or dry-mix process was used.



In determining which coating materials to use in future lock wall repairs, a careful cost/benefit evaluation should be made. Based on present observations, it is likely that conventional shotcrete will give a few to several years of good service. The glass-fiber and glass-fiber-latex coatings will give better service for successively longer periods of time, but at respectively greater initial cost.

## SECTION V - REPAIR CONTRACT

Based on laboratory tests and the field demonstration, it was decided that the lock could and should be repaired by coating it with the latex-modified fiberglass-reinforced mortar. As early work progressed on preparation of bidding documents, the job presented a number of interesting problems and questions. Some of the more interesting ones were:

1. How should surface preparation be specified and how could the Government reliably get satisfactory results?
2. How could the understandability high-risk factor that contractors would apply to the job be minimized?
3. Should the job go out as fixed price to a low bidder, should it be negotiated, or should it be "cost-plus"?
4. Could "sole source" materials be used?
5. Should the job be set aside for small businesses?
6. Since there could be no time extension, how would partial payment be handled if the job was only partially completed?
7. What prequalifications of bidders and the workmen should be required, if any?
8. How should the technical provisions of the specifications for which there were no guides be worded?

## SURFACE PREPARATION

The success of the repairs was totally dependent upon satisfactory surface preparation. No matter how good the coating itself was, it would be useless if it did not bond to the existing wall. During the field demonstration, difficulties were encountered in getting an acceptably prepared surface. There always was a question of "how clean is clean." The contractor, designer, and field inspectors all had different concepts of what could and should be accomplished. Results of the field demonstration clearly showed that if the surface is not cleaned of all loose, unsound, and friable materials, the coating will become loose and fail.

Prior to preparing the bid documents, several additional surface cleaning trials were made under purchase order and time and materials arrangements to verify that with properly operating and used high-pressure water-jet equipment, the surface could be satisfactorily cleaned. Sandblasting equipment, wire brushes, hand chipping, and air-operated scabblers were also tried by the Government designers. The benefit of this experience was passed on to the bidders through a prebid conference, discussion on the technical provisions of the bidding documents, and with photographs of the work which also became a part of the bidding documents. Exhibit 5 contains the actual bid document and contract wording with regard to surface cleaning. Plate 5 contains photographs of some of the Government's surface cleaning experiences which were also part of the bid documents.

There is no device or test which could be used to measure the degree of "clean" necessary and actually achieved. It was totally a judgmental thing based on a description expressed in the bid documents. This caused concern among the Corps' contract administration group but was an unavoidable situation. In actuality, for the main repair contract it did not turn out to be a problem. The situation is not really any different than occurs when preparing lifts of mass concrete for

subsequent placements or when preparing a foundation for concrete or earthfill. Good judgment must be used and there is no qualitative test that can be applied. To minimize disagreements and the application of different standards by different inspectors, and to establish with the contractor right from the start what would be acceptable, the contract required preparing "sample areas" before progressing with clean up of the entire lock. This was done in areas of minimal, medium, and serious deterioration. The contractor's foreman, field supervision, and company owner were there. The Corps had its designer, shift supervisors for inspection, and head of the construction administration division present. The equipment to be used in the actual cleaning was used in the demonstration. Agreement was easily reached as to what was required and what was an acceptable condition. This standard was then used throughout the job.

Most of the actual cleaning was done between lockages over a three-week period before the lock outage and actual spray-up coating operations began. High-pressure water-jet equipment was used and normally operated at about 10,000 psi. As the nozzle tips would wear out, the pressure would start to drop to about 7,000 psi. New tips were then installed. Both the pressure and angle of the jet were critical to effectively remove unsound materials. Occasional handchipping was used to supplement the water jet where it just didn't clean well enough. Usually the unsound mortar was about 1/4-in. to 3/8-in. thick and flaked off easily. For most of the area in the lower portion of the lock, scaling had already occurred to a depth of 1/2 to 2 in. in the mortar, severely exposing the large aggregate which itself was quite sound. Plate 5 shows the cleaning operation.

#### BID DOCUMENTS

The bidding documents were very specific and descriptive. They included a narrative of what the problem was and the repair objectives.

Discussions of Government experience with such things as satisfactorily cleaning the deteriorated surface were included in the specifications for the bidder's benefit. The "drawings" included photographs of the project and developmental work. Specifications required use of experienced and trained key personnel and workmen. An extensive quality control program was clearly spelled out and a detailed CPM was required. The most applicable parts of the bidding documents are contained in Exhibit 5. There were no modifications to the bid documents after they became the contract. There also were no claims.

Some of the most important aspects of the bidding stage were to first interest contractors into bidding the specialized high-risk project, then to minimize the risk, and finally be sure the bidders understood the project. The specifications were written with more dialogue and in a more descriptive manner than normally would be done. Comments from bidders showed that they appreciated this approach, especially the discussions about what the purpose of the project was and what the Government experience had been with cleaning and application of the coating.

A pre-bid conference was held which included a question-answer period and open dialogue between bidders and the designer, inspection crew, and operational personnel from the project. The designer explained what the concrete problem was and what this repair needed to accomplish. A slide show was given showing the previous year's trials and the surface cleaning procedures. Contractual problems experienced during the trials were discussed. After the conference a tour through the lock was conducted. Ten contractors attended the conference, including the successful low bidder. The pre-bid conference was probably one of the reasons for the success of the job and the lack of claims and modifications.

The process to be used for securing a contractor was not clear-cut at first. Because of the highly specialized nature of the job,

consideration was given to negotiating a contract with a qualified and experienced contractor. Consideration was also given to doing the work on a "time and materials" basis. It was finally decided that the job should be put out as a fixed-price low-bid contract. There are perhaps 5 to 10 contractors in the United States that would be able to do the amount of spray-up coating required on this job with skilled applicators. Most of these are small organizations that work under controlled plant conditions and make precast panels. They would need the support of a large construction contractor to organize, mobilize, access, and manage the lock repair in a remote site. It was decided that there would be sufficient qualified contractors or joint-ventures to get competitive bidding if the standard low-bid process were used.

The method of measurement and payment for the job was also debated. Options included paying for man hours, equipment rental, and materials; one job lump-sum; and paying by the square foot for surface preparation and satisfactory coating. Because the total area to be done was easily defined and the mix was clearly established, it was decided to simply pay for mobilization as one item with the actual work as the only other item. Progress payments were made based on actual invoice records for mobilization costs and for the percentage of actual areas completed. Interim payments were made on a two-week schedule.

The lump-sum instead of unit-price method of payment had distinct advantages and disadvantages. It greatly simplified record keeping and accounting. However, if the job were not completed in the very tight construction time allowed, the value of the completed work would be difficult to establish. In actuality, the job would at that time probably have been subject to claim and negotiations anyway, so having a unit-price item would only have given a starting point for the arguing. Having a lump-sum pay item had a psychological advantage. It left no doubt that the intent was to finish the entire job - not just as many square feet as could easily be done - and that the amount paid was fixed.

Permission from higher authority was required to specify sole source material suppliers for the fiber glass fiber and the latex. It was easily justified based on (1) the fact that all developmental work and testing had been with these materials and there was a possibility that materials from another source would not be successful and this did not allow comparative testing, and (2) they were the only known sources that would meet the "Buy America Act" requirement.

Permission was also necessary to gain relief from putting the job in the "Small Business Set-Aside" category. This was justifiable in order to get competitive bidding and to let the small contractor who had the spray-up expertise but not the financing or organizational capability do the work as a subcontractor to a reliable large prime contractor.

The Government estimate and three bids were as follows:

	<u>Mobilization</u>	<u>Surface Preparation and Coating</u>	<u>Total</u>
Government	\$145,600	\$ 885,000	\$1,030,600
Bidder 1	437,000	742,057	1,179,057
Bidder 2	419,000	933,000	1,352,000
Bidder 3	900,000	1,046,000	1,946,000

The Government estimate was originally \$937,000 total, or 25.8 percent below the first low bidder. A review of the estimate found errors which increased it to \$1,030,600 or well within 25 percent of the low bidder which was a criterion for award of the contract.

## CONSTRUCTION

The contractor, Premier Waterproofing Company, Denver, Colorado, is a reputable small general contractor experienced with various forms of specialty concrete construction, but who at that time had no experience in the spray-up process. The specifications clearly required various degrees of experience for the nozzlemen and actual applicators. The foremen were required to have had at least two years' experience with shotcrete and at least two of the nozzlemen were required to have served at least six months' apprenticeship with the same type of equipment used on the job. All other nozzlemen were required to have had at least two weeks' of "hands-on" training. Each spray-up crew was required to demonstrate their ability to perform satisfactorily and to apply coatings of the required quality by placement.

The contractor met these requirements in two ways. First, he hired all available experienced spray-up crews from two companies that specialize in this work. One was from Maryland and the other was from California. Second, he set up a training center in a warehouse for his own personnel and had them practice for two weeks before going to the jobsite. During this training, a knowledgeable factory representative for the fiberglass supplier gave "hands-on" instruction and one of the experienced crews worked with the new crews for about two days. After meeting the minimum experience requirements, each nozzleman made a sample panel from which test coupons were cut. These were examined visually for laminations, porosity, fiber distribution, and appearance. They were then measured for thickness and subjected to center point flexural testing. The panels were made on two different occasions and tested by the same laboratory, but at different ages. Results were as follows:



### GROUP 1

22 Panels, 44 Coupons, 2 days' age when tested.

Thickness: Average = 11/32-in.  
Range = 1/4 to 1/2-in.  
Standard deviation = 1/16-in.  
Coefficient of variation = 20%

Flexural Strength: Average = 4,910 psi  
Range = 1,997 to 7,261 psi  
Standard deviation = 1,276 psi  
Coefficient of variation = 26%

Appearance: Density, fiber distribution, and general appearance ranged from fair to good.

### GROUP 2

11 Panels, 22 Coupons, 5 days' age when tested.

Thickness: Average = 3/8-in.  
Range = 1/4 to 9/16-in.  
Standard deviation = 1/8-in.  
Coefficient of variation = 30%

Flexural Strength: Average = 6,491 psi  
Range = 4,428 to 8,743 psi  
Standard deviation = 1,255 psi  
Coefficient of variation = 19%

Appearance: Density, fiber distribution, and general appearance ranged from good to excellent.

The mix used for all trials was the same as specified and used throughout the contract work. It was identical to the latex-modified glass-fiber-reinforced sprayed-on mortar coating used in the field demonstrations of the previous year. The batch weights and volumes were as follows:

<u>Item</u>	<u>Weight, lb/cu yd</u>	<u>Approximate Volume, ft.<sup>3</sup></u>
Water	245	4
Cement	1,720	9
Fibers	117	1
Latex	520	7
Fine Aggregate (SSD)	860	5
W.R.A., oz	75	
Air	3.7%	1
		<u>27 ft.<sup>3</sup></u>

The cement used was portland cement Type I-II. The fibers were single-strand, multiple-filament, alkali-resistant fiberglass. The latex contained approximately 50 percent solids and an antifoaming additive. The fine aggregate was presacked sand. The water-reducing agent met the applicable requirements of ASTM C 494.

The contract allowed the use of Government-furnished and stockpiled fine concrete sand or prepackaged contractor-furnished manufactured sand. The concrete sand had a better particle-size distribution and in the trials gave the best results, but its larger particle size made it possibly more susceptible to plugging the small nozzle aperture and the problems of handling it in bulk outweighed the minor increase in cost for the contractor to supply his own packaged material. The prepackaged sand also eliminated problems with variations in moisture content and grading that otherwise could be expected in an open bulk stockpile. Fine aggregate gradings were as follows:

<u>Percent Passing</u>		
<u>Sieve</u>	<u>Bulk Stockpile</u>	<u>Prepackaged</u>
9.5-mm (3/8-in.)	100	100
4.75-mm (No. 4)	99	100
2.36-mm (No. 8)	88	100
1.18-mm (No. 16)	63	99
600- $\mu$ m (No. 30)	36	72
300- $\mu$ m (No. 50)	19	9
150- $\mu$ m (No. 100)	9	2
75- $\mu$ m (No. 200)		0

One week before the lock was taken out of service for the actual repairs the contractor was required to go through a full-scale demonstration of his operation during a 24-h lock shutdown. The demonstration required cleaning and coating an upper lift of the lock wall. It gave the contractor and crews a chance to find out ahead of time what problems might be encountered during the actual project shutdown and gave them time to react to the day's experience before getting into the three-week-outage period.

The contractor had two basic approaches that could be used to accomplish the work during the three-week outage. Each would require "around the clock" operations to finish in time. He could either work from scaffolding (built up from the bottom or suspended) with the lock unwatered, or he could work from a floating barge. The first alternative presented major problems in assembling the scaffold quickly and in providing a mobile platform that could be moved as the work area moved. Scaffolding the entire lock was simply not feasible.

The contractor chose to work from a floating plant consisting of six barges, three working at each wall and lashed together end-to-end. The barges stretched for about 75 percent of the length of the lock. The lashed barges were braced and welded side-by-side so that they all acted as one unit. At the start of the lock outage, the barges were floated into the lock chamber and positioned. The lock was filled and the contractor began working from the top lift down. After the approximate height of one 5-ft lift was coated from end-to-end on each side, the lock level was lowered about five feet and the next lift was coated. A major drawback to this system was a delay required by specifications of eight hours between when the water was lowered below an area of wall and when that area could be coated. This time was selected as a safe and reasonable period which would allow hydrostatic pressure within pores of the concrete to stabilize with atmospheric conditions. Without this stabilizing time, it was felt that the coating could be applied, but that hydrostatic and vapor pressure would

prevent the coating from tightly bonding to the base concrete. Another specification restriction required that the surface be rinsed of any silt or contamination from the lock water and be in a saturated surface dry or drier condition at the time the coating was applied. Because of the need for some final clean up and surface drying, the fact that the barge had about 5 ft (one lift) of freeboard, and the fact that the contractor could not coat more than one 5-ft lift in eight hours, the hydrostatic pressure stability period did not represent any real delay to the construction sequence.

In order to coat the wall below minimum tailwater, it was necessary at the end of the job to set the downstream lock chamber bulkhead and partially unwater the lock so the barge floated below tailwater. This procedure worked satisfactorily. After completion of the spray-up work, the water level was kept below the last of the coating until it air dried for 36 h as required by the specifications. In actuality, the contractor finished about one day earlier than necessary and the coating was able to receive a little bit more beneficial drying before being inundated by reflooding of the lock chamber to full tailwater elevation. As discussed earlier, unlike conventional mortar, in order for the latex-modified mixture to properly work, it needs to go through a period of drying.

On the barges, the contractor had storage areas for the cement, latex, aggregate, fibers, and admixture; sanitation facilities; a quality control laboratory; surface preparation equipment; a small repair shop; spare equipment and parts; and four independent mixing, batching, and spray-up stations. Personnel initially got on and off the barge by access ladder at shift changes, but when the climb became over about 20 ft, all access was limited to man skip and crane. Near the end of the job this meant about a 125-ft total lift.

Each spray-up station had its own scales, spray-up gear or nozzle, mixer, and pump. Each station was also manned by a full crew consisting of a nozzleman, mixer man, roller man, and usually a helper. As described earlier, the "spray-up" process sprays a wet mortar mixture pumped to the nozzle by grout pump and atomized with low-pressure air at the nozzle. While the mortar is sprayed against the wall surface, fiberglass fibers are simultaneously chopped from a continuous strand and blown into the mortar spray from a separate cutter head attached to the nozzle. The material is applied in a thickness of about 1/8 in. per pass and must be lightly rolled with what looks like a serrated paint roller between successive passes. This presses the glass fiber into intimate contact with the mortar. A mat of material results which is heavily reinforced but which will sag or fall off if too much weight is added too fast. The final surface could be troweled; but although this makes a better appearance, it was unnecessary and if overdone could be damaging.

There were two types of mixers used, a conventional agitator with rubber blades and a high-shear type. The high-shear type proved to be more effective as it could mix smaller quantities faster, approximately one cubic foot at a time. However, it should be noted that overmixing with the shear mixer, especially in the case of latex, could be damaging and must be avoided. The conventional agitator was slow and occasionally would hold up the spray crew while it was mixing. It could mix up to 4 ft<sup>3</sup> at a time.

There are a number of manufacturers of the cutter head assembly. The contractor used only two brands of equipment on this job, thereby minimizing spare parts inventories.

Because there was often some last minute final surface cleanup that needed to be done just ahead of the spray-up work, the nozzle men occasionally had to wait until this work was completed. This resulted

in delay not only because of waiting for the cleanup, but because during the wait the mixture would thicken in the nozzle or pump lines and plug the equipment. It could take anywhere from 30 s to 30 m to free these plugs. There also was a problem with spray guns plugging between shifts. It was found that the most efficient way to minimize this problem was to keep the nozzle open and continually pumping grout even if this meant recycling fresh grout back into the mixer or wasting it.

The air temperature and the temperature of the lock wall had a bearing on the amount of water used in the slurry mixture. The roller-men had difficulty in keeping the fiber concrete from sliding off the lock wall in cool weather. The ambient temperature ranged between 37 and 62<sup>0</sup> Fahrenheit during the lock outage. The nozzleman would first make a pass with just the slurry and fiber. He would then make two or three passes with the slurry and fiber to obtain a 3/8-in. thickness. During operation, the spray gun had to be held perpendicular to the surface to obtain a uniform mix on the wall. The distance the gun was held from the wall varied, but the best results were obtained at approximately two feet. In between each pass of slurry and fiber, the surface had to be rolled until there were no loose fibers sticking out.

As the work progressed from the upper lifts which had less deterioration to the lower lifts with substantial deterioration, the length of fiber used had to be adjusted. The cutter heads were designed to chop fibers of 1-1/2-in., 4-1/2-in., or a combination of 1-1/2- with 3-in. lengths. The longer fibers were desired because of their believed tendency to give greater toughness and strain capacity. However, where the depth of relief around large exposed aggregate was about 1/2 in. or more, the long fibers tended to bridge across adjacent pieces of aggregate leaving an air void over the relief between them. Where a combination of 1-1/2- with 3-in. fibers was used, this problem was minimized.

Horizontal joints were treated by simply spraying over them and treating them as a continuous mass. These joints have no known movement across them and are tight construction lift joints. They did present some problem because they had a 3-in. chamfer into which the coating had to be sprayed and rolled. There was a tendency for the workmen not to adequately coat or roll these places.

Vertical joints between monoliths were known to have relative movements of measurable amounts. Wherever these were encountered, the joint was over-sprayed from one side to the other, but then the joint line was cut through the coating with a knife while it was still wet. Some joints that were not cut with the knife later were cut with a diamond saw.

#### QUALITY CONTROL

Quality control was an essential and continuous task both from the standpoint of production and in-place quality. If the high-quality job required was not achieved during application and surface preparation, the coating could be expected to fail and the project would have been a waste of time and money. From the contractor's standpoint he did not have the time nor latitude to go back and repair any defective materials, nor could he afford to have anything other than consistent mixes of the correct proportions to keep the equipment operating and the nozzleman working.

Minimum requirements for a detailed quality control program were described in the contract documents. Exhibit 5 of this report contains that information as it appeared in the contract. The quality control program as it was actually carried out is described below. The contractor approached Quality Control (Q.C.) with a good attitude. He hired a highly qualified consulting materials engineer to head up the program full time and acquired the services of a private Q.C. testing firm to provide support personnel. A Q.C. engineer was on the job and

working full time during every minute of every shift of placement. In reality the best control of mix quality turned out to be the practical aspect that if the mix was too wet it would slough off of the wall, and if it was too thick it would plug up the equipment. It had to stay within very close tolerance to go through the equipment and stay on the wall at 3/8-in. thickness.

The testing and monitoring program as it was actually performed consisted of the following:

1. Although surface preparation was probably the most important part of the job, it was the area where Government inspectors thought the contractor's quality control organization exercised the least control. Fortunately the Government had a shift supervisor and at least one inspector performing quality assurance checks at all times throughout the entire job so overlooked areas of inadequate surface cleaning were caught.

2. A sieve analysis of the sand was performed every shift. Moisture contents were checked occasionally and ranged from 0.0. to 0.5 . If bulk or open stockpiles of aggregate were used, gradation and moisture tests would have been more important and required more frequent tests. However, the prepackaged commercial bags of manufactured aggregate were tightly controlled at the bag plant by the manufacturer so the frequency of testing on the jobsite could be relaxed.

3. Batch sizes of the mixtures remained constant throughout the job so that only one weight or volume of each material was ever used per batch with the possible exception of slight moisture content variations as required by quality control and quality assurance personnel to account for temperature changes and humidity. The sand and cement was batched by even bag counts. Admixture was measured to the same mark in the same beaker for each batch. A mark was placed in the water and



latex buckets to show what volume corresponded to the correct batch weight as checked on the scales.

4. Air content of the slurry mixture was determined by the pressure method (ASTM: C 231). The percentage of air ranged between 3.6 and 8.6%, and averaged 6.0%. It was checked several times a day.

5. The fiber length ranged between 1-1/4 and 5-1/4 in. A 1-1/2-in. and 3-in. combination was desired over much of the job with some areas calling for only 4-in. lengths. Fiber lengths were continually monitored and adjusted when necessary.

6. Flow and workability tests were carried out by the nozzle men using a specialized cylindrical "flow cone" test developed for this purpose. As stated before, a slight variation in the mix consistency would mean that it would either fall off the wall or plug up the equipment.

7. The amount of rebound ranged between 0.4 and 4.1% and averaged 2.4%. This approximation was based on visual and weight measures. The amount of rebound depended mostly on the nozzle man. The rebound percentage does not reflect the total amount of waste due to over-shooting, etc. The actual amount of waste was more than expected. The contractor began to run short of materials before the end of the job and had to air-freight additional supplies to the site.

8. "As shot from the nozzle" mixture proportions of the fiber and slurry combination were checked every shift. One method used was to run the spray gun for a given period of time collecting the fiber and slurry separately. They were then weighed to determine the percentage of fiber. A second method was performed by obtaining a sample of the fibrous coating from the wall while it was still wet. The fiber and slurry were washed out separately and weighed. The latex had a tendency to stick to the fibers and could not be washed off completely; however, both tests were comparable. These tests were run on a continuous basis.

9. Ambient temperatures ranged between 37<sup>0</sup> F in the early morning and 62<sup>0</sup> F during the day. It was checked for high and low during each day.

10. Two 24-in.-square test panels were made against plywood sheets for each monolith. Later record tests and historical data were obtained from these panels. The test panels are considered to be a good representation of the work done. They represent both the actual material used and workmanship of the various nozzlemen, and were made under actual placing conditions. Exhibit 6 contains results to date of these tests. Additional testing, including quality and strength after storage in a damp environment for a year, will be made.

11. The final in-place thickness varied between 5/16 and 5/8 in. and averaged 3/8 in. In areas where 3-in. aggregate was visible on the lock wall, the thickness over the outside of the 3-in. cobbles was less than 3/8 in., but between the aggregate particles it was more than 3/8 in. Since the protection is really needed over the mortar between the aggregate, this was considered acceptable. Thickness was continuously checked by stabbing the wet mix with a nail used as a depth gage.

#### ADMINISTRATION

Close cooperation among engineering, construction, and operations personnel of the Corps was essential. In addition to the "constructability review," several in-house meetings were held during development and planning. The design engineer attended the contractor's pre-work conference and visited the contractor's home office during training of his applicators. An extensive written discussion of "Engineering Considerations for Field Personnel" was prepared by the designer for construction personnel, and a meeting to discuss all engineering aspects of the job was held with the inspectors. When qualification panels were made, the designer worked side-by-side with the contractor's nozzlemen and made a test panel of his own right along with them - fortunately, it turned out

very well. This did a lot for morale, giving the workers a close feeling of responsibility and importance of the job. During visits to the contractor's training facilities, video tapes were made and brought back for study by other district personnel. To help the contractor, especially because he was a smaller contractor and pay estimates were very high, they were made every two weeks.

During construction, an experienced shift supervisor from the Corps' Construction Division (GS-11 or 12) was in charge of contract administration in the field for each shift. They were assisted by inspectors from Engineering Division, Construction Division, a Resident Engineer's office, and the "Engineer-in-Training" Program for recent college graduates. Inspector personnel overlapped shifts. The project designer made frequent visits to the jobsite and observed operations during each shift.

A detailed critical path method (CPM) diagram was required from the contractor and carefully reviewed by the Government. Also required were a safety plan, hazard analysis, and a plan of operations showing interaction between the contractor and Government crews operating in the lock area at the same time. The contractor avoided potential subcontract administration problems and paperwork by hiring on his own payroll personnel from other companies who worked with him. This way, all employees and work were always under his direct control. During construction, the contractor kept "up to the minute" progress records in his field office. Also, during the critical three-week outage, company officers, including the president, moved to the jobsite from their home office and became intimately involved with the entire operation.

This approach to running the job by Government and contractor personnel took much effort, planning, and overtime, but it paid off. The contractor proudly admits to a substantial profit which was well deserved.

The job was completed on time with no accidents, no claims, and no modifications. There was no unscheduled delay to navigation traffic. The Corps is very satisfied with the quality of the work.

#### COST

An abstract of bids is given in subsection "Bidding Documents" of this report. The total actual contract cost was \$1,179,057. Of this \$437,000 was for mobilization, demobilization, and for access to the remote site. Of the remaining \$742,057, it is estimated that about \$150,000 or \$1.00/ft<sup>2</sup> covers the cost of materials used in the coating, \$2.20/ft<sup>2</sup> covers the cost of applying the coating, and about \$1.60/ft<sup>2</sup> covers the cost of surface preparation.

#### OUTSIDE INTEREST AND POTENTIAL USES

There has been substantial outside interest in this project by Corps and private organizations. During construction, there were many visitors from various Corps' districts, divisions, and laboratories. Since completion of the repairs, there have been many requests for information about the project and many inquiries concerning its applicability to other deteriorated locks, etc.

The Corps has many other deteriorating locks which might be repaired much more rapidly and economically with the spray-up method, assuming this method demonstrates satisfactory durability during future exposure. Where areas of severe spalling or deterioration need patching, this could first be done with conventional shotcrete, dry pack, anchored concrete pourbacks, or epoxy. The system has other potential applications for lining eroded conduits, providing protection from sea water, lining lagoons, spillway face aprons, etc. Each potential application must be critically evaluated with the understanding that this system may work in some cases, but might not be the best solution for what might seem like similar conditions in other cases.

## SECTION VI - PERFORMANCE

At the time of this writing, the lock has been in service for six months since repairs were completed, so an evaluation of actual long-term performance cannot yet be made. However, the previous year's trial coating did go through a winter and performed well where the base surface was properly prepared beforehand. Laboratory tests of freezing and thawing show that essentially no damage should occur and other testing indicates that the coating will prevent the base concrete from becoming critically saturated. About two days after the last of the repair coating was placed, the lock was put back into service and subjected to frequent lockages with substantial impact of barges banging against the wall and scraping it. There was no failure. Photographs on Plate 8 show where some of this rubbing occurred and that the coating remains intact, even where it abruptly juts out from places like at the armor steel around the ladder recesses.

After about four months of service, an area about 5 ft<sup>2</sup> broke loose, but this is over one of the previous trial coatings of a different mix that had been placed in the preceding year. The failure is in the old trial material, not in the spray-up coating.

It would be too optimistic to hope that out of 150,000 ft<sup>2</sup> of area there will be no failure with time. From just a practical construction standpoint, it would be reasonable to assume that somewhere in all that area the mix was not quite right or the surface did not get adequately cleaned. If the job were 99 percent effective, there would be allowance for 1,500 ft<sup>2</sup> of area to fail. Performance, though, is expected to be much better. Fortunately, one major advantage of the coating is that any small failed areas can be repaired rather easily and quickly with operations' personnel by mixing up a latex mortar slurry, adding the fibers directly into the mixture, and hand plastering it onto the wall.

Another approach to evaluation of the repair is that even if it had to be redone every five or ten years, the savings in time and money over conventional repairs still make it a preferred method. However, it is thought that the repairs will be permanent and this will not be necessary.

EXHIBIT 1

CLIMATOLOGICAL AND LOCK USAGE DATA

<u>Item</u>	<u>Description</u>
1	Monthly Temperature Data
2	Freeze-Thaw Cycles Based on Daily Ambient Tempera- ture Changes
3	Commercial Lockages

MONTHLY TEMPERATURE DATA, °F

1971

<u>Average</u>	<u>Highest</u>	<u>Lowest</u>	<u>Month</u>
39	64	17	January
41	64	22	February
43	65	20	March
51	75	33	April
62	90	41	May
63	97	46	June
77	108	48	July
81	108	53	August
63	91	42	September
54	85	22	October
44	58	27	November
36	55	16	December

1973

33	54	5	January
40	64	25	February
48	67	31	March
54	78	33	April
63	98	41	May
68	104	47	June
78	106	51	July
76	107	52	August
67	98	48	September
55	74	35	October
42	62	30	November
42	57	21	December



MONTHLY TEMPERATURE DATA (Continued)

1975

<u>Average</u>	<u>Highest</u>	<u>Lowest</u>	<u>Month</u>
35	57	12	January
36	57	18	February
44	61	27	March
48	69	30	April
59	86	39	May
65	93	46	June
77	111	55	July
71	97	51	August
69	94	48	September
--	--	--	October
43	73	18	November
--	--	--	December

1977

--	--	--	January
42	70	25	February
45	70	28	March
55	91	31	April
58	80	38	May
73	97	35	June
74	98	42	July
79	107	52	August
64	88	44	September
54	79	35	October
42	67	13	November
38	61	15	December

CYCLES OF FREEZING AND THAWING

Based on Daily Ambient Air Temperature Changes

<u>1971</u>	<u>1973</u>	<u>1975</u>	<u>1977</u>	<u>1979</u>	<u>Month</u>
11	15	17	16	3	January
15	18	15	16	13	February
14	2	11	3	7	March
0	0	3	0	2	April
0	0	0	0	0	May
0	0	0	0	0	June
0	0	0	0	0	July
0	0	0	0	0	August
0	0	0	0	0	September
3	0	0	0	0	October
7	9	9	10	23	November
<u>18</u>	<u>5</u>	<u>16</u>	<u>19</u>	<u>17</u>	December
68	49	71	64	65	TOTAL

COMMERCIAL LOCKAGES

<u>Year</u>	<u>Number of Commercial Lockages</u>
1973	920
1979	1376

<u>Monthly</u>	<u>Number of 1979 Commercial Lockages</u>
January	64
February	62
March	53
April	125
May	179
June	156
July	157
August	156
September	94
October	85
November	85
December	83

## EXHIBIT 2

### REPORT OF TESTS ON ORIGINAL CONCRETE TAKEN FROM THE LOCK WALL

<u>Item</u>	<u>Description</u>
1	NPDEN-GS-L Letter and Laboratory Report dated 29 August 1975.
2	Strength, Modulus of Elasticity, and Freeze/Thaw Durability for the Original Lock Wall Concrete
3	Graphs of Dynamic Modulus vs. Freeze/Thaw Cycles for the Original Lock Wall Concrete
4	Report of After-Test Examination of Freeze/Thaw Beams Saved from Navigation Lock Repair Concrete Debris

ADDRESS REPLY TO  
DIRECTOR  
NOT TO INDIVIDUALS

U. S. ARMY ENGINEER DIVISION NORTH PACIFIC  
CORPS OF ENGINEERS  
NORTH PACIFIC DIVISION MATERIALS LABORATORY  
RT 2 BOX 12A  
TROUTDALE OREGON 97060

NPDEN-GS-L (75-C-797)

29 August 1975

SUBJECT: Navigation Lock Repair, Lower Monumental Dam, Report of Tests  
on Concrete Debris, Contract DACW 68-75-C-0113

District Engineer, Walla Walla  
ATTN: NPWEN-FM

1. Please reference your DA Form 2544 request No. E-86-75-0128 dated 25 April 1975.
2. Attached is report of tests on two samples of concrete debris (LM No.- 1 & 2) taken from the Lower Monumental Navigation Lock repair site 5 March 1975. (Received 7 Mar 75). Included are:
  - a. Inclosure 1, Summary of Tests on Concrete Debris including compressive strength, tensile strength, modulus of elasticity and freeze-thaw.
  - b. Inclosure 2, NPD Form 361 "Resistance of Concrete Beams to Accelerated Freezing and Thawing".
  - c. Inclosure 3, Report of After Test Examination of Freeze-Thaw Beams.
  - d. Inclosure 4, Plates I, II, III, & IV.
    - (1) Plates I & II, photograph of samples as received.
    - (2) Plates III, IV, photograph of freeze-thaw beams after test.
3. Freeze-thaw beams were sawn from concrete chunks by diamond saw to have one formed concrete face and three sawn faces. During sawing and coring of specimens it was found much of the debris had internal cracks reducing the number and size of specimens available. Five nominal 3x4x14-inch beams were obtained from sample LM-1 and one from sample LM-2. Tensile splitting and compressive strength tests were made on 4x8 and 2x4-inch cores respectively drilled with diamond bits from the remnants of the concrete debris. Modulus of elasticity was measured on the 2x4-inch cores by surface mounted SR 4 wire strain gages.

EXHIBIT 2  
Item 1  
Page 1 of 2

NPDEN-GS-L (75-C-797)

29 August 1975


SUBJECT: Navigation Lock Repair, Lower Monumental Dam, Report of Tests  
on Concrete Debris, Contract DACW 68-75-C-0113

Visual inspection of the debris indicated sample LM-1 contained 3" MSA  
and sample LM-2 1½" MSA.

4. Analysis of the freeze-thaw beams during and after test indicated  
the formed face concrete was of poor quality. Formed surfaces had  
suffered severe mortar losses by 55 cycles of freeze-thaw exposure and  
were completely destroyed by 300 cycles of freeze-thaw. The interior  
concrete (sawn faces) was generally of better quality with light to  
medium mortar losses. (Incl. 2 & 3)

5. This completes all work requested.

Incl  
as

  
C. E. BORGE  
Director

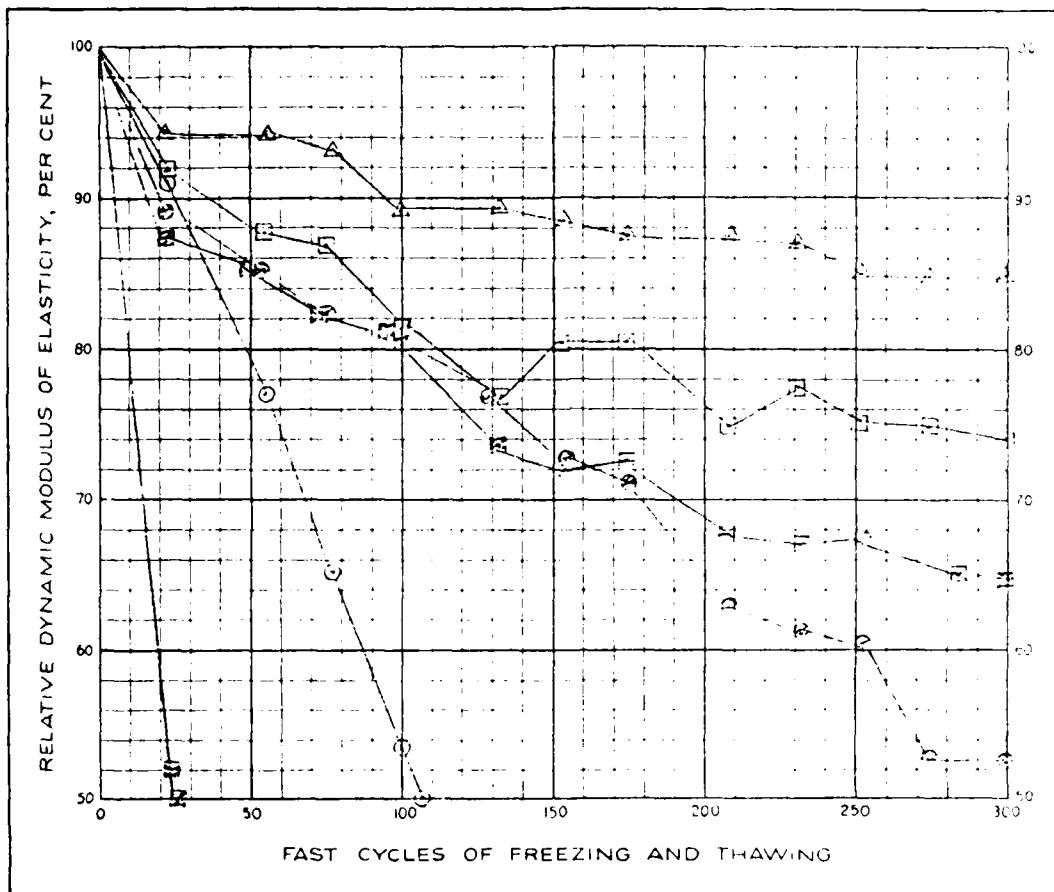
NPDEN-CS-L (75-C-797)

29 August 1975

LOWER MONUMENTAL DAM

Summary of Tests on Concrete Debris Samples from Navigation Lock Repair - Contract DACW 68-75-C-0113

Debris Sample No.	Core No.	Diameter in.	Length in.	Modulus of Elasticity Ex10-6 psi	Tensile Splitting psi	Compressive Strength psi	Accelerated Freeze-Thaw, DFE 300
LM-1	1	2.07	4.0			6570	
	2	2.07	4.1			5170	
	3	2.07	4.05	4.92		7040	
	4	2.08	4.05			6540	
	5	2.07	3.95	5.09		6480	
	6	2.07	4.05			5110	
	9	2.07	4.05			5850	
	10	2.07	4.0		530	3270	
	7	3.92	7.0		620		
	8	3.92	7.2		575		
	Average			5.01		5750	58.3
LM-2	1	2.07	4.05			3540	
	2	2.08	3.95			3840	
	3	2.07	4.0	1.78		4820	
	4	2.08	4.0			3390	
	5	2.07	4.0	2.80		3540	
	6	3.92	7.0			5560	
	7	3.92	7.2		510		
	8	3.92	5.4		400		
	Average			2.29	455	4110	4.2



LM  
"  
"  
"  
"  
LM

BEAM NO	SYMBOL	DIE AT 300 CYCLES	NO CYCLES REL E = 50%	PROJECT
1-1	⊙	17.8	107	LOWER MONUMENTAL NAVIGATION LOCK REPAIR
1-2	△	82.9		DISTRICT WALLA WALLA
1-3	□	74.0		FINE AGGREGATE
1-4	⊗	52.2		N/A
1-5	▲	64.7		COARSE AGGREGATE
2-1	■	4.2	25	N/A

REMARKS	
On nominal 3x4x14-inch concrete beams sawn from navigation lock debris.	

Plotted JP	75-C-797
Checked	
29 Aug 75	

NPD FORM 361 JUNE 49	RESISTANCE OF CONCRETE BEAMS TO ACCELERATED FREEZING AND THAWING CORPS OF ENGINEERS NORTH PACIFIC DIVISION TESTING LABORATORY
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## LOWER MONUMENTAL DAM

## Report of After Test Examination of Freeze-Thaw Beams Sawn from Navigation Lock Repair Concrete Debris

1. Samples & Tests

Six nominal 3x4x14-inch beams were sawn from two samples of Lower Monumental navigation lock repair concrete debris, five beams from sample LM-1 and one beam from sample LM-2. The beams were subjected to accelerated freezing and thawing and tested in accordance with CRD-C-20. Beams were selected and sawn to have one formed face and three sawn faces each. Beams No. LM 1-1, 2, 3 and 5 appeared to contain 3" MSA and beams No. LM 1-4 and LM 2-1, 1½" MSA. Following are detailed test results:

Sample & Beam No.	MSA in.	No. Cycles Tested	Rel. E <sub>300</sub> of each Beam	Rel. E = 50 of each Beam	Wt. Loss %	Depth of Erosion of Beam Faces in.	
						Formed	Sawn
LM 1-1	3	132	17.8	107	6.8	0.5	0.1-0.2
2	3	306	82.9		8.0	0.75	0.1-0.2
3	3	306	74.0		7.9	0.65	0.1-0.2
4	1½	306	52.2		9.0	0.3	0.3
5	3	306	64.7		7.2	0.5	0.1-0.2
Average			58.3		7.7	0.55	0.1-0.3
LM 2-1	1½	78	4.2	25	1.2	0.1-0.2	0.1-0.2

2. Examination of Beams

The concrete of beams No. LM 1-1, 2, 3 and 5 was of variable quality. The formed faces (exterior surfaces) had heavy mortar losses and the original contours were completely destroyed. The sawn faces (interior surfaces) had light to medium mortar losses and the original contours were rounded to subrounded. The mortar ranged from soft to firm on the formed faces and was firm on the sawn faces. Mortar-coarse aggregate bond was good. The coarse aggregate was generally sound with one to two soft particles noted per beam. Two to three spalls ranging up to two inches in diameter and one inch in depth were also noted on each beam.

Beams No. LM 1-4 and LM 2-1 did not show much difference between the formed and sawn faces as did No. LM 1-2, 3 & 5. Mortar losses ranged from light to medium and the original contours were rounded to subrounded. Mortar was generally firm with some soft areas and mortar to coarse aggregate bond was good. Beam No. LM 2-1 broke in half in 55 to 78 cycles and was removed from test at 78 cycles.

General physical quality of these two beams was poor.

29 August 1975

The depth of penetration of destructive freeze-thaw action is illustrated by the dark wet edges of the sawed sections in the accompanying photographs. The 1/2-inch thick slices were sawn from third points of the beams, air-dried, placed in 1/4-inch deep water for 15 minutes and photographed.

The beams would be rated poor to excellent according to EM-1110-2-2000 "Standard Practice for Concrete", page 2-11, paragraph 4.

EXHIBIT 3

INVESTIGATIONS OF ORIGINAL CONCRETE IN THE LOCK

<u>Item</u>	<u>Description</u>
1	NPDEN-GS-L Letter Dated 18 May 1978 Containing Entrained and Entrapped Air Contents for Original Lock Wall Concrete and for Remade Mixes
2	Report of Durability Tests on Mables Pit Aggregate Concretes (Original Construction Aggregates)
3	Graphs of Dynamic Modulus vs. Freeze/ Thaw Cycles for Mables Pit Aggregate Concretes (Original Construction Aggregates)
4	Narrative Discussion and Data for Mables Pit Aggregate Concretes (Original Construction Aggregates)
5	Petrographic Report for Mables Pit Aggregate Concretes (Original Construction Aggregates)



DEPARTMENT OF THE ARMY  
NORTH PACIFIC DIVISION, CORPS OF ENGINEERS  
P.O. BOX 2870  
PORTLAND, OREGON 97208

NPDEN-GS-L (77-C-5)

18 May 1978

SUBJECT: Lower Monumental Navigation Lock Chamber Concrete  
Durability Studies

District Engineer, Walla Walla  
ATTN: NPWEN-FM

1. Please reference:

a. Your DA Form 2544 request No. E86-96-0016 dated 14 July 1976.

b. Telcons 5 October, 9, 14, and 23 November 1977 with Messrs. Houghton, NPDEN-GS and Schrader, NPWEN-FM in which air content tests by the microscopical method on samples of concrete debris from the Lower Monumental Navigation Lock Chamber (rec'd 8 and 25 Nov 77) were requested.

c. Telcon 9 November 1977 in which your Mr. Schrader confirmed the transmittal of stockpiled natural sand and gravel from Mabels Pit, Snake River, WA (rec'd 8 Nov 77).

d. Telcon 24 January 1978 in which Mr. Houghton was given results of air content tests on the first samples of concrete debris.

e. DF dated 2 February 1978 from Mr. Houghton to NPDEN-GS-L requesting slump loss and freeze-thaw tests be made on 3" MSA concrete batched with Mabels Pit sand and Mathews Terrace coarse aggregate.

f. Telcon 6 February 1978 with Mr. Houghton wherein it was agreed that:

(1) Volcanic cinders pozzoland would be used in lieu of calcined shale.

(2) The standard laboratory mix sequence would be used.

2. The purpose of this study was to investigate two possible causes for the low entrained air content found in the lock chamber concrete.

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SUBJECT: Lower Monumental Concrete Durability Studies

Parameters studied included:

- a. Effect of slump loss on air content.
  - b. Effect of additional consolidation effort required due to slump loss on air content, freeze-thaw durability and compressive strength.
  - c. Effect of mixer grinding with 3-in MSA aggregate on the release of montmorillonite clay from the sand with possible subsequent effect on the size or distribution of the air-void system.
3. Attached with results complete to date is report of air content and durability studies made on concrete debris and recently cast concrete batched with Mabels Pit sand and Mathews Terrace coarse aggregate. Included are:
- a. Incl 1, Summary Report of Durability Tests.
  - b. Incl 2a-c, NPD Form 361, Graphical Report of "Resistance of Concrete Beams to Accelerated Freezing and Thawing" for the three sets of beams tested.
  - c. Incl 3, Report of After-Test Examination of Accelerated Freeze-Thaw Beams.
  - d. Incl 4a-b, Photographs of Slices sawn from selected freeze-thaw beams after test.
  - e. Incl 5, Report of Petrographic Examination of Mabels Pit sand.
  - f. Incl 6, NPD Form 359, Report of Concrete Mixture Design for the 3" MSA mixture used in these studies.
  - g. Incl 7, ENG Form 6008-R "Report of Test of Portland Cement" for the stock of lab-blend cement batched in the concrete mixes.
  - h. Incl 8, ENG Form 6000-R "Report of Tests on Pozzolan" for the Sun brand ground volcanic cinder pozzolan batched in the concrete mixes.
4. Approximately 64 sq in x 1 inch thick slabs were sawn from two samples of 3" MSA concrete debris sampled at the Lower Monumental Navigation Lock. Slabs were forwarded to the Waterways Experiment Station for determination of the air content by the modified point count method "CRD-C 42-71"

NPDEN-CS-L (77-C-5)

SUBJECT Lower Monumental Concrete Durability Studies

Microscopical Determination of the Air-Void Content in Hardened Concrete. Additional tests were made on slabs sawn from representative freeze-thaw beams recently cast from 3" MSA laboratory mixed concrete. Results of the tests on the debris and recently cast concrete are as follows:

NPDP No.	Location	% Aggregate	% Paste	% Entrained Air	% Entrapped Air	% Total Air
313	Sawn 1" from Surface of Lift No. 25	76.3	22.0	1.2	0.5	1.7
325	From Lock Chamber Rubble pile @ Base of Nav Lock	76.2	20.5	2.9	0.4	3.3
386-9	3" MSA * Recently Cast Fit Beams- Cast With- out Delay	60.3	34.4	3.9	1.4	5.3
386-18	3" MSA * Recently Cast Fit Beams. 30 Min. Delay	57.4	36.1	5.3	1.2	6.5

NOTE: A REVIEW OF THE ORIGINAL DATA SHEETS SHOWS THAT THESE ROWS OF DATA WERE PREVIOUSLY ENTERED BECAUSE OF A TYPING ERROR.

\* WGT SCREENED minus 3/4" fraction of mixture.

5. Tests were made on three batches of 3" MSA concrete batched with Mables pit sand and Mathews Terrace aggregate, a laboratory blend of three Type II cements, of volcanic cinder pozzolan and neutralized vinsol resin air entraining agent. The quantity of pozzolan used was based on a 20% replacement of Portland Cement by absolute volume. Project mix design No. 3-5.25P-2B was selected for this study; however, the mixture required reportioning to an equivalent cement content of 4.94 cwt/cu yd to meet design slump and air requirements. The equivalent water cement ration was maintained at 0.44 (W/C+P = 0.45). The mixture was designed for 5.0% entrained air and 2 1/2 inches slump on the minus 1 1/2" fraction. The air

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SUBJECT: Lower Monumental Concrete Durability Studies

content of the 3" and + 3/4" concrete fractions were 4.0 and 6.1% respectively. Mixing and plastic concrete testing procedures were as follows:

- a. Batch all ingredients;
- b. Mix three minutes;
- c. Rest three minutes;
- d. Mix two minutes and discharge;
- e. Wet screen to minus 1 1/2";
- f. Split concrete into two equal samples;
- g. Make air content slump test and cast 6 x 12-in cylinders and 3 1/2 x 4 1/2 x 16-in freeze-thaw beams from one sample leaving second sample undisturbed;
- h. Wait 30 minutes and
- i. Without agitating or remixing repeat steps g and h on the second undisturbed concrete sample.

6. Cylinders were cast for test at 7, 28 and 90 days; and freeze thaw exposure was initiated on the beams at age 28 days. To serve as a control series 3/4" MSA P.C. concrete batched with Mabels pit natural sand and Mathews Terrace gravel was tested according to CRD-C 114-73 "Method of Test for Soundness of Aggregate by Freezing and Thawing of Concrete Aggregates". The control beams were started in test at a standard 14-day age, and cylinders were cast for test at age 7, 14, 28 days.

7. The petrographic report indicates that about six percent of the sand is composed of soft particles with some montmorillonite clay in the finer fractions. Slump loss tests indicated significant stiffening occurred during the 30-minute delay. Average slump for the three batches was reduced from 10 inches as mixed to 3/4" in 30 minutes. Delayed concrete appeared "stiff" and lumpy, lacked plasticity and workability, and tend to "pothole" during consolidation. It is estimated that two to three times as much effort was required to produce adequate consolidation of the delayed tested concrete. However, the delay had negligible effect on the plastic air content and the durability factor of the concrete. The average air content for the mixed and delayed concrete was 5.2 and 5.0%, respectively, and the durability factors for the mixed, delayed and standard freeze-thaw test

NPDEN-GS-L (77-C-5)

SUBJECT: Lower Monumental Concrete Durability Studies

beams were DFE = 89.7, 86.7, and 92.3, respectively. These DFE factors would rate all of the beams as excellent, which is comparable with DFE = 84.2 reported in Lower Monumental Lock & Dam Concrete Aggregate Design Memorandum No. 8, 28 April 1961. Compressive strength results at age 28 days for the mixed and 30-minute delay 3" MSA concrete were 3480 and 3430 psi, respectively. Detailed test results are attached.

8. The results of this investigation to date indicate the following:

a. Microscopic analysis of debris from spalled navigation lock chamber concrete showed entrained air contents ranging from 1.2 to 2.9 percent, which are too low to provide a high level of freeze thaw durability.

b. Microscopic analysis of the freeze-thaw beams cast from delayed and non-delayed recently cast concrete showed a decrease in entrained and total air content for the delayed concrete as compared to the non-delayed concrete.

c. Two to three times more compaction effort was required to consolidate the stiff 30 minute delayed concrete as compared with the non-delayed concrete.

d. No significant reduction in the plastic air content was measured in concrete allowed to set for 30 minutes prior to test.

e. The extra consolidation required to consolidate the stiffened concrete had no apparent effect on its freeze-thaw durability or compressive strength.

9. This completes all works requested.

FOR THE DIVISION ENGINEER:

Incl (dupe)  
as

  
O. E. BORGE  
Director

CF:  
NPDEN-GS  
Concrete

5.

EXHIBIT 3  
Item 1  
Page 5 of 5



NPDEN-GS-L (77-C-5)

LOWER MONUMENTAL NAVIGATION LOCKS  
Report of Durability Tests - Mabels Pit Aggregates

NPDEN Mix No.	MSA 3"	Batch No.	Plastic Test 1/			Compressive Strength, psi 1/						Accelerated 2/ Freeze-Thaw Diff. 300' F Mixed 30 Min		
			Air Content Mixed 2/ 30 Min 3/	Slump Mixed 2 1/2 3/4	3/	7-Day		14-Day		28-Day			90-Day	
						Mixed	30 Min	Mixed	30 Min	Mixed	30 Min		Mixed	30 Min
386		1	4.8	4.5	2 1/2	2380	2680	3690	3740	3790	3830	90.3	86.1	
			5.5	5.2	2 3/4	2370	2320	3320	3310	3480	3330	89.4	88.1	
			5.3	5.2	2 1/2	2350	2470	3360	3290	3270	3360	89.4	85.9	
			5.2	5.0	2 1/2	2280	2340	3270	3360	3480	3430	89.7	86.7	
311	3/4"	1	6.4	2 3/4	3	3040		3370		4040		92.9	-	
		2	6.6	2 1/2	3	2870		3260		3810		93.5	-	
		3	5.7	2 1/2	2 1/2	2680		3040		3500		90.6	-	
		4	5.7	2 1/2	2 1/2	2730		3000		3620		-	-	
		5	6.0	2 3/4	2 3/4	2830		3170		3740		-	-	
		Avg	6.1	-	2 3/4								92.3	-

NOTE: 1/ On Wet Screened Minus 1 1/2" Concrete

2/ On Wet Screened Minus 3/4" Concrete

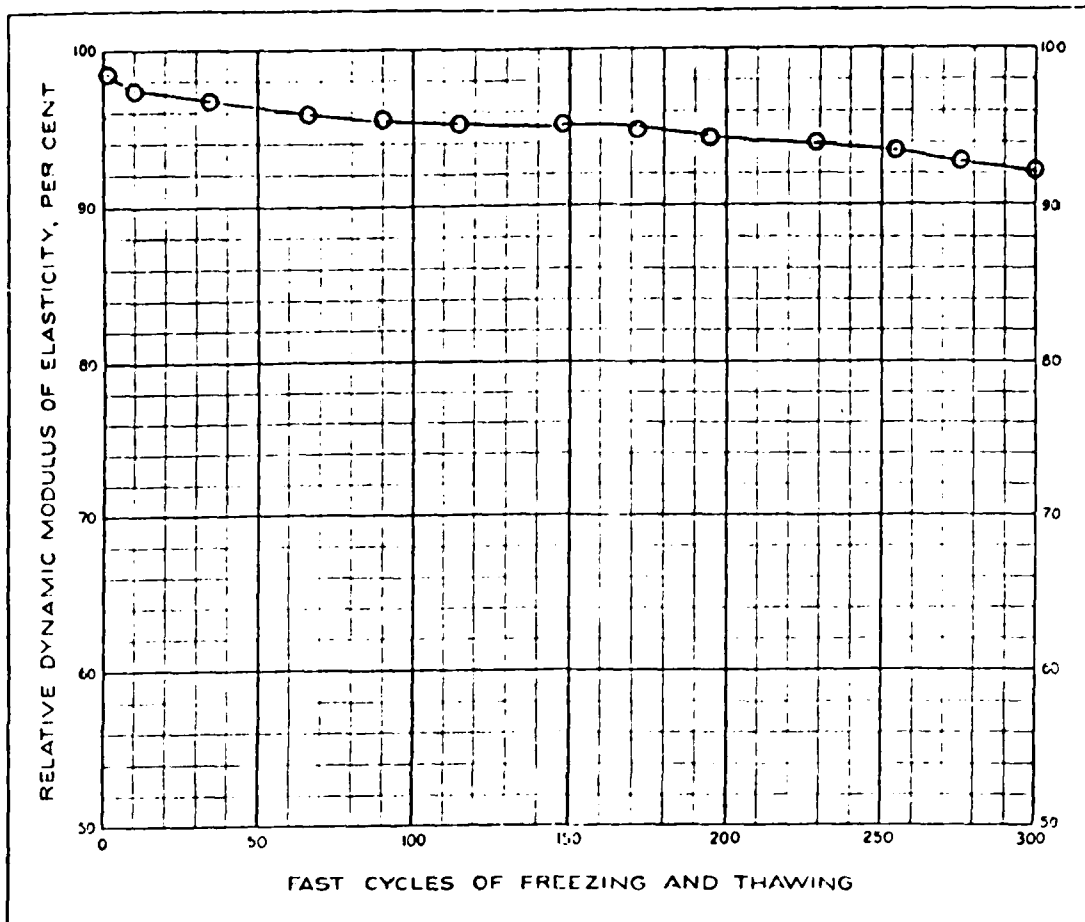
3/ Specimens cast for two test conditions as follows:

- Mixed-plastic tests made 6 specimens cast immediately after 8 minutes laboratory mixing sequence.
- 30-Min-plastic tests made and specimens cast after 30 minute delay without remixing and with a minimum of rehandling.

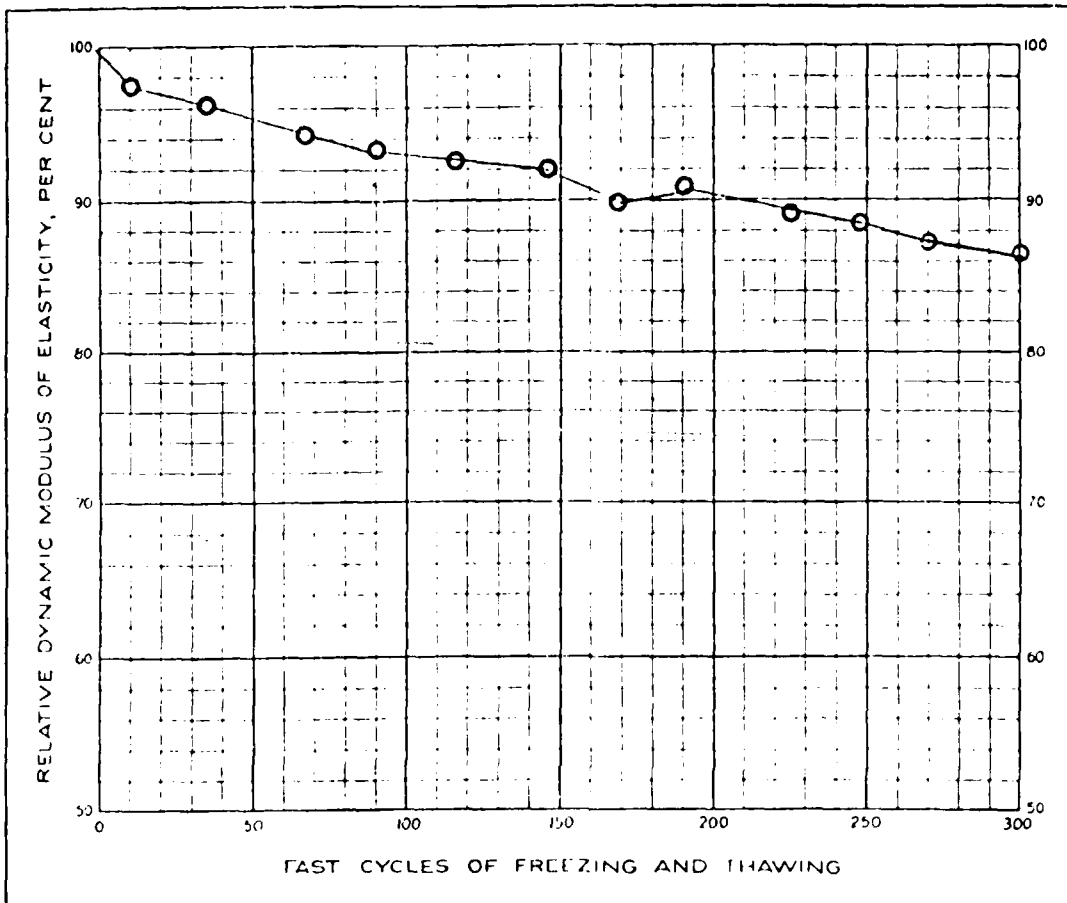
4/ Freeze-thaw tests started at age 28 days

5/ Freeze-thaw tests started at age 14 days, average for three specimens/batch.

GENERAL: Concrete was stiff and "lumpy" appearing after 30-min delay; slump test indicated concrete lacked plasticity and workability; estimated that concrete required two to three times as much vibration to provide adequate consolidation to eliminate "potholing" as compared with non-delayed concrete.



BEAM NO	SYMBOL	DPE AT 300 CYCLES	NO CYCLES REL E = 50%	PROJECT
311		92.9		<b>LOWER MONUMENTAL CONCRETE DURABILITY STUDIES</b> DISTRICT Walla Walla FINE AGGREGATE Laboratory processed natural sand, Mabels Pit, Snake River, WA COARSE AGGREGATE Laboratory processed natural gravel, Mathews Terrace, Snake River, WA
311 A		93.5		
311 B		90.6		
Average	○	92.3		
REMARKS Designed according to CRD-C 114, 3/4" MSA @ 0.49 W/C.				Plotted JP Checked W/O NO 77-C-5 James A. Paxton
RESISTANCE OF CONCRETE BEAMS TO ACCELERATED FREEZING AND THAWING CORPS OF ENGINEERS NORTH PACIFIC DIVISION TESTING LABORATORY				



BEAM No.	Symbol	Def. at 100 Cycles	Def. at 300 Cycles	PROJECT
386		86.1		<b>LOWER MONUMENTAL CONCRETE DURABILITY STUDIES</b> DISTRICT <u>Walla Walla</u> FINE AGGREGATE Laboratory processed natural sand, Mabels Pit, Snake River, WA COARSE AGGREGATE Laboratory processed natural gravel, Mathews Terrace, Snake River, WA
386 A		88.1		
386 B		85.9		
Average	O	86.7		
REMARKS Cast from wet screened minus 3/4" portion of project Mix No. 3-5.25 P-2B. 30- Minute delay prior to casting.				Plotted <u>JP</u> W/O NO Checked _____ 77-C-5 James A. Paxton

TEST FORM 361 JUNE 1955	RESISTANCE OF CONCRETE BEAMS TO ACCELERATED FREEZING AND THAWING CORPS OF ENGINEERS NORTH PACIFIC DIVISION TESTING LABORATORY
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## LOWER MONUMENTAL CONCRETE DURABILITY STUDIES

## Report of After Test Examination of Accelerated Freeze-Thaw Beams

1. Samples & Test - Three sets of beams, each composed of three beams from each of three concrete batches, were cast with laboratory processed Mabel's Pit sand and Mathews Terrace Course aggregates. One set, NPD No. 311, was cast from a 3/4" MSA concrete mixture designed and tested in accordance with CRD-C 114 and two sets, NPD No. 386, were cast from the wet screened minus 3/4 portion of a 3" MSA Lower Monumental project Mixture, No. 3-5.25P-2B, one set immediately after mixing and one set after a 30-minute delay without agitation or remixing. The P.C. concrete beams were started in test at age 14-days, the P.C. pozzolanic concrete, at age 28 days. The beams were subjected to 301 to 308 cycles of rapid freezing and thawing and tested in accordance with CRD-C 20. Following are detailed test results:

Series & Set No.	MSA	Test Condition	Cement Content		Air Content, %	Slump ins.	DFE 300	
			cu. yd	Pozz			Ind.	Average
311	3/4	CRD-C 114	6.11	none	6.4	2 3/4	90.3 92.8 95.7	92.9
311A	3/4	CRD-C 114	6.11	none	6.6	3	94.1 92.8 93.6	93.5
311B	3/4	CRD-C 114	6.11	none	5.7	2 1/2	90.2 91.3 90.4	90.6
Average			6.11		6.2	2 3/4	92.3	
386	3"	Cast without delay after	4.94	30.0	5.8	2 1/2	90.7 89.4 90.8	92.3
386A	3"	Mixing	4.94	30.0	6.7	2 3/4	90.1 88.7 89.4	89.4
386B	3"	Mixed	4.94	30.0	6.4	2 1/2	88.4 89.6 90.2	89.4
Average			4.94	30.0	6.3 1/2	2 1/2	89.7	
386	3"	Cast after 30-min. delay	4.94	30.0	5.4	3/4	87.5 85.7 85.1	86.1
386A	3"	delay	4.94	30.0	6.2	3/4	87.3 89.0 88.1	88.1
386B	3"		4.94	30.0	6.2	1	87.2 83.5 87.1	85.9
Average			4.94	30.0	5.9 1/2	3/4 2/2	86.7	

NOTE: 1/ On the minus 3/4" portion of the mixture.

2/ On the minus 1 1/2" portion of the mixture.

2. Examination of Beams - All beams are of good physical quality. Beams have well preserved original contours and mortar coarse aggregate losses are minor. The mortar is firm and the bond is good. Minor popouts are present in all beams. The beams cast after the 30 minute delay had the highest weight loss, greater surface relief and had lost some 1/2 inch aggregate particles. Details are as follows:

<u>Series No.</u>	<u>Test Condition</u>	<u>Weight Loss, %</u>	<u>Surface Relief, ins</u>
311	CRD-C114	5.8	0.15
386	Standard	6.4	0.15
386	30 min. delay	10.2	0.25

The depth of penetration of destructive freeze-thaw action is illustrated by the dark wet edges of the sawed sections in the accompanying photographs. The accompanying block illustrates the original size of the test beams. The 1/2 inch thick sections were sawn from selected beams, air dried, placed in 1/2 inch deep water for 15 minutes and photographed immediately. The average DFE<sup>300</sup> durability factors of 92.3, 89.7, and 86.7 would rate the beams as excellent by criteria outlined in EM-1110-2-2000, "Standard Practice for Concrete" Page 2-11, para. 4.

DEPARTMENT OF THE ARMY  
MISSOURI RIVER DIVISION, CORPS OF ENGINEERS  
DIVISION LABORATORY  
OMAHA, NEBRASKA 68102

MRD Lab. No. 77/288

Sheet 1 of 3  
16 MAR 1978

Subject: Petrographic Examination of Fine Aggregate,  
Report Series No. 1

Project: Lower Monumental Dam  
Intended Use: Concrete Aggregate  
Source of Material: Mabel's Pit on Snake River

Submitted by: Director, North Pacific Division Laboratory  
Date Sampled: -, Date Received: 10 December 1977  
Method of Test or Specification: CRD-C 127-67

References: North Pacific Division Laboratory Request No. E85789500  
(DTL 78-4) dated 8 December 1977.

SAMPLE IDENTIFICATION

MRD Lab. No. 77/288. Sample of concrete sand (NPDL-311) from  
Mabel's Pit on the Snake River for Lower Monumental Dam.

SUMMARY OF EXAMINATION RESULTS

1. The fine aggregate is dark brownish-gray, rounded to angular, partially manufactured sand consisting of about 70 percent dense basalt, 2 percent vesicular basalt, 5 percent highly weathered basalt and clay, 6 percent granite, 7 percent quartzite and quartz, 4 percent feldspar, and 6 percent miscellaneous materials.
2. Porous, absorptive, friable particles comprised mainly of weathered basalt and silty calciche total about 6 percent of the sample. Some chlorophaeite and montmorillonite clay are included in this group in the finer sieve fractions.
3. Although some natural glass is present with a refractive index of less than 1.540, the alkali-silica reactivity potential of this aggregate is thought to be minor.
4. Most of the particles tend to have an equidimensional shape with a smooth to moderately rough surface texture, and are free of any coatings, except for small spots of calcite incrustation on some particles.

MRD FORM 115  
MAY 70 EDITION OF FEB 67 IS OBSOLETE.

16 MAR 1978

5. The composition of the sand by sieve fractions is given in the attached table.

COMPOSITION AND PHYSICAL PROPERTIES

6. Basalt. Black and brown, dense to vesicular basalt particles make up 72 percent of the sand sample, while soft, moderately to highly weathered basalt comprises 5 percent. Most of the basalt is holocrystalline but a few contain interstitial natural glass. In a few cases, the glass (palagonite) has a refractive index less than 1.540 which makes it susceptible to alkali-silica reaction. In addition a trace amount of glassy rhyolite rock is also present. However, the amount of glass in the entire sand is small and not likely to cause excessive reactivity when used in concrete. In some of the weathered basalt particles, the natural glass has altered to chlorophacite which in turn is altered to montmorillonite clay. Since the sand contains a high percentage of minus No. 200 size material and much of the clay is collected in this size fraction, it would be advisable to remove some of this material by washing before the aggregate is used in concrete.

7. Granite. Fine-grained, light gray to pink, hard, dense, rounded to angular granite particles occur in small amounts in the larger sieve fractions making up about 6 percent of the sand. Practically all of these particles appear sound and durable.

8. Quartzite and Quartz. The particles of this group consist of rounded to angular, hard, dense, white to buff, fine-grained quartzite and angular, white to colorless quartz. Most of the quartzite occurs in the coarser sieve fractions, while quartz grains are most abundant in the finer sizes. All of the grains of this group are hard and durable. This group totals about 7 percent of the sand.

9. Feldspar. This group is made up of microcline and plagioclase feldspar grains having been derived from the granitic and basaltic rocks, largely as a result of crushing. Most tend to be fresh, but a few show alteration products such as sericite and kaolinite. The grains are white to gray, rectangular, and have good cleavage surfaces. Feldspar comprises about 4 percent of the fine aggregate.

MRD Lab. No. 77/288

Sheet 3 of 3

16 MAR 1978

10. Miscellaneous. A number of different rock types and minerals are included in this group such as mica schist, concrete, calciche, and limestone in the coarse fractions and mica, calcite, and common detrital minerals in the fine sizes. All together this group makes up about 0 percent of the sand. Some of the calciche and limestone particles are soft and highly absorptive.

Submitted by:

A handwritten signature in dark ink, appearing to read 'R. K. Schlenker', with a long horizontal flourish extending to the right.

R. K. SCHLENKER

Director, MRD Laboratory



TABLE 1 - COMPOSITION OF FINE AGGREGATE

Lower Monumental Dam											MND Lab. No. 77/299	
											Weighted Average (A)	
Passing Sieve		No. 4	No. 8	No. 16	No. 30	No. 50	No. 100	No. 200	No. 4			
Retaining Sieve		No. 8	No. 16	No. 30	No. 50	No. 100	No. 200	Pan	Pan			
Constituents		Amount as Number of Particles in Percent										
Dense Basalt	83	86	71	61	51	50	45	70				
Vesicular Basalt	12	4	1	-	-	-	-	2				
Weathered Basalt	2	3	4	5	11	12	15	5				
Granite	-	5	9	7	8	-	-	0				
Quartzite and Quartz	-	1	0	14	19	12	10	7				
Feldspar	-	1	4	2	4	19	20	4				
Miscellaneous (B)	3	-	5	11	7	7	10	0				
TOTALS		100	100	100	100	100	100	100	100	100		

(A) Based on the distribution of constituents by sieve fractions shown above and on the grading as received.

(B) Includes mica schist, concrete, caliche, limestone, mica, calcite, and common detrital minerals.

EXHIBIT 4

PRELIMINARY EVALUATION TESTING OF SPECIALIZED MORTAR COATINGS

<u>Item</u>	<u>Description</u>
1	DA Form 2544 dated 28 June 1976 Describing the Wet-Dry - Freeze/ Thaw Specialized Test Under Various Pressures
2	NPDEN-GS-L Letter Dated 27 September 1976 Giving Results of Specialized Laboratory Freeze/Thaw Tests on Mortar-Coated Lock Concrete
3	NPDEN-GS-L Letter Dated 18 February 1977 Giving Results of Comparative Tests of Fiberglass-Reinforced Mortar Coatings With and Without Latex When Subjected to Freeze/Thaw

<b>INTRA-ARMY ORDER FOR REIMBURSABLE SERVICES</b> <small>For use of this form, see AR 37-108 and AR 37-110; the proponent agency is Office of the Comptroller of the Army.</small>		1. RECEIVING OFFICE CONTROL NUMBER	
		ORDER	
		2. NUMBER	3. DATE 14 June 1976
		4. CHANGE ORDER	
		5. NUMBER	6. DATE
7. ORDERED BY: (Command, Installation or Activity, and address) (Include ZIP Code) District Engineer Walla Walla District, Corps of Engrs. City-County Airport Walla Walla, WA 99362		8. TO BE PERFORMED BY: (Command, Installation or Activity, and address) (Include ZIP Code) Director Division Materials Lab. North Pacific Division, Corps of Engrs. Troutdale, OR 97060	
9. DESCRIPTION OF SERVICES TO BE PERFORMED  Perform special freeze-thaw/wet (under pressure)-dry tests on samples of Lower Monumental concrete that have been coated with Glass Con. The coating has been applied by a private company and 8 samples have been shipped to NPDL. Special jigs as shown on the attached sketch should be made by the laboratory for these tests. Two samples should be retained for possible testing at a later date—one sample should be subjected to the standard freeze-thaw test, and the remaining five samples should be subjected to the pressurized wet-dry, freeze-thaw test as described below.			
<u>Test Procedure</u>  Clamp the samples in the jig as shown on the attached sketch. The bolts should be evenly tensioned so that their total initial load will be equal to the force exerted against the top plate by the air pressure.* Air dry the samples in the jig. Fill the reservoir between the top plate and the Glass Con surface about half way with water. Apply the required air pressure* and maintain it for 1 hour. Release the pressure, empty the water, and totally freeze the test specimen. After the total specimen has been frozen, remove it from the freezing chamber and immediately fill the reservoir about half way with cool water. Apply the required air pressure again, being sure that the water is not frozen at the time air pressure is applied. Repeat the process until failure or 300 cycles.			
(CONTINUED)			
10a. NAME AND TITLE OF ORDERING OFFICER RICHARD L. GULLIXSON Chief, F&M Br.		b. SIGNATURE  c. DATE 28 Jun-76	
ORIGINATING FINANCE AND ACCOUNTING OFFICE APPROVAL			
11a. ACCOUNTING CLASSIFICATION BFLM305X3B0000 96x3122 Const. Gen CE Civil		b. AMOUNT \$13,000.00	
c. CHANGE INCREASE AMOUNT _____ DECREASE AMOUNT _____ REVISED AMOUNT _____			
12. Services to be performed pursuant to this order are properly chargeable to the appropriations or other accounts indicated above until _____ the expiration date of this order. <small>(Day - Month - Year)</small>			
10b. TYPED NAME AND TITLE OF APPROVING OFFICER T. W. MORSE Ch, F&A Branch		b. SIGNATURE  c. DATE	
ACCEPTING OFFICER			
11. THE ABOVE TERMS AND CONDITIONS ARE SATISFACTORY AND ARE ACCEPTED.			
a. TYPED NAME AND TITLE OF ACCEPTING OFFICER		b. SIGNATURE  c. DATE ACCEPTED	

DA FORM 2544

REPLACES PREVIOUS EDITION OF THIS FORM AND DA FORM 1819, 1 JAN 67 OF WHICH WILL BE ISSUED AND USED UNTIL 1 OCT 68 UNLESS SOONER  
 U.S. GOVERNMENT PRINTING OFFICE: 1965 O-770-747

NWEN-FM

SUBJECT: Performing Special Freeze-Thaw/Wet-Dry Tests on Lower Monumental  
Concrete Samples

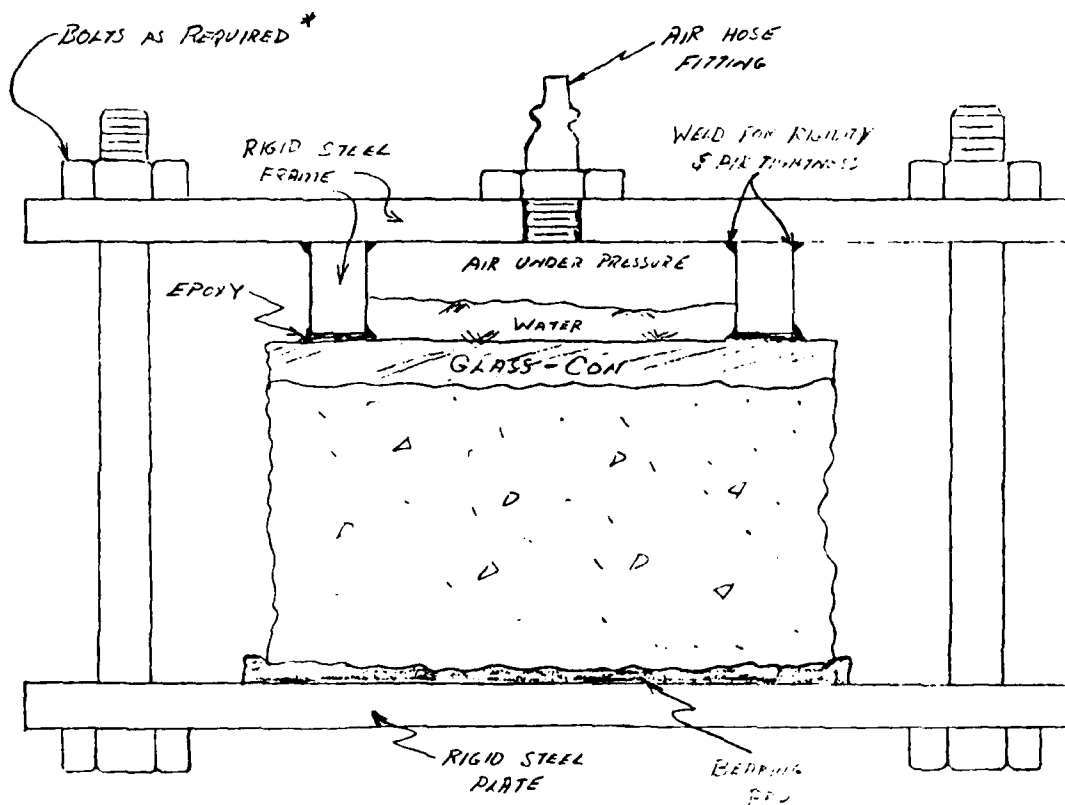
*Sample #1	-	pressure equals	1 to 2	psi
" #2	-	"	"	11 psi
" #3	-	"	"	22 psi
" #4	-	"	"	33 psi
" #5	-	"	"	44 psi

The amount authorized by this order may not be exceeded without prior approval of this office.

Billing will be on SF 1080 or other applicable media and will cite the order number shown in Block 2a above, indicating either a partial or final billing. Receipt of final billing will constitute a termination of this order and an automatic withdrawal of any unused balance.

BY *EKS* DATE *6/25/76* SUBJECT *JIG FOR L-MANIPULATOR*  
 CHKD BY DATE *FACILE THE TEST OF*  
*GENS-CON SAMPLES*

SHEET NO. *OF*  
 JOB NO. *OF*



\* CLAMP TOP AND BOTTOM PLATES TOGETHER. BOLTS SHOULD BE EVENLY TORQUED SO THAT THE FORCE ON THE EPOXY SEAL IS ZERO WHEN THE SYSTEM IS PRESSURIZED.

ADDRESS REPLY TO  
DIRECTOR  
NOT TO INDIVIDUALS

U.S. ARMY ENGINEER DIVISION, NORTH PACIFIC  
CORPS OF ENGINEERS  
NORTH PACIFIC DIVISION MATERIALS LABORATORY  
HT 2 BOX 12A  
TROUTDALE OREGON 97060

NPDEN-GS-L (77-C-5)

27 September 1976

SUBJECT: Lower Monumental Navigation Lock Repair, Preliminary Report of  
Freeze-Thaw Tests on Fiberglas Coated Concrete Beams

District Engineer, Walla Walla  
ATTN: NPWEN-FM

1. Please reference DA Form 2544 request No. E-86-99-0016 dated 14 July 1976 with inclosed drawing.
2. Following, with results complete to date, is report of freeze-thaw tests made on six nominal 3.5x4x10-inch fiberglas coated concrete beams.
3. Beams were sawed from chunks of concrete sampled during the navigation lock repairs (Ref. NPDL W/O 75-C-797). A nominal 1/2 inch layer of fiberglas coating (Glass-Con) was applied to one 3x4x10-inch face by a private company. One beam was subjected to the standard CRD-C20-75 freeze-thaw test exposure and five are currently being subjected to the pressurized wet-dry freeze-thaw test requested. One additional sample has been retained for possible testing at a later date.
4. The 1/2-inch fiberglas coating was essentially destroyed by 300 cycles of rapid freeze-thaw as follows:

<u>Cycles of Freeze-Thaw</u>	<u>Remarks</u>
99	Estimated 2/3 coating remains
178	Coating thickness = 0.25"
261	21 pieces of stone visable through fiberglas
300	Stones visable throughout coating, loose fibers in remaining fiberglas. Estimated thickness: 0.0-0.10"

DPE300 = 69.7

Wt. Loss = 15%

A photograph was taken of the eroded surface which will be forwarded when available.

EXHIBIT 4  
Item 2  
Page 1 of 2

27 September 1976

Subject: Lower Monumental Navigation Lock Repair, Preliminary Report of  
Freeze-Thaw Tests on Fiberglass Coated Concrete Beams

5. Five beams are currently being tested by the requested pressurized freeze-thaw method at pressures of 2, 11, 22, 33, and 44 psi. The beams are assembled in jigs which allows water under the above pressures to be applied against the fiberglass coated face. The jigs are loaded to insure a minimal compressive load on the fiberglass concrete interface when the pressure is applied. The test procedure is to remove the beams from the freezer, set in ambient air for one hour, for thawing inspect for damage, apply water under pressure for one hour, drain the water and return to the freezer. One cycle is completed per day. The requested wetting-drying portion of the test is not applicable as the beams stay moist throughout the test due to condensation, etc. The five beams have 23 to 25 cycles of freezing and thawing to date with no visible damage.

6. Additional results will be forwarded as available.

*Wilbur P. Roberts*  
for O. E. BORGE  
Director

ADDRESS REPLY TO  
DIRECTOR  
NOT TO INDIVIDUALS

U S ARMY ENGINEER DIVISION, NORTH PACIFIC  
CORPS OF ENGINEERS  
NORTH PACIFIC DIVISION MATERIALS LABORATORY  
RT 2 BOX 12A  
TROUTDALE OREGON 97060

NPDEN-GS-L (77-C-5)

18 February 1977

SUBJECT: Lower Monumental Navigation Lock Repair, Report of Freeze-Thaw  
Tests on Glass-Con Fiberglass Slabs

District Engineer, Walla Walla  
ATTN: NPWEN-FM

1. Please reference:
  - a. Your DA Form 2544 request No. E86-99-0016 dated 14 July 1976.
  - b. Our report this subject dated 27 September 1976.
  - c. NPD Form 300 dated 27 December 1976 covering transmittal of two nominal 3/4x3x5-inch samples of Glass-Con, one with and one without latex admixture.
2. Attached, completing all work requested, is report of freeze-thaw tests on the above mentioned samples.
3. The Glass-Con slab without latex (Sample No. 1) had gained in height and weight and started to split along the longitudinal axis by 47 cycles of freeze-thaw. At 95 cycles it appeared the sample could have been separated with finger pressure. The test was terminated at 214 cycles. The slab with latex (Sample No. 2) showed no measurable or visual deterioration after 300 cycles of freeze-thaw.
4. Photographs of the beams after test will be forwarded when available.

1 Incl (dupe)  
as

  
O. E. BORGE  
Director

Copy furnished:  
NPDEN-GS

EXHIBIT 4  
Item 3  
Page 1 of 2



18 February 1977

## LOWER MONUMENTAL NAVIGATION LOCK REPAIR

## REPORT OF ACCELERATED FREEZE-THAW TESTS ON GLASS-CON SLABS

		Sample No.			
		1		2	
		W/O Latex		With Latex	
1. Type					
2. Dimensions: Inches		0.8X3X5		0.4-0.8X3X5	
		Test Results			
No. Cycles <sup>1/</sup> F/T	Weight <sup>2/</sup> Chg. %		Height <sup>2/</sup> Chg. %		Remarks
	1	2	1	2	
10	-	-	-	-	No visible action.
47	+2.7	0	+15.1	0	No. 1 - Surface spalling, splitting on axis. No. 2 - No action.
69	+1.4	+0.9	+18.7	0	No. 1 - Sand size particles eroding, crack widening. No. 2 - No action.
95	+2.7	+0.9	+29.5	0	No. 1 - Surface eroding, sample splitting in half. No. 2 - No action.
128	+2.7	+0.9	+17.1	0	Same as above.
155	-10.4	+0.9	+15.1	0	No. 1 - Washed slab prior to measuring, all surfaces eroded, crack extends through slab. No. 2 - No action.
193	-	-	-	-	Continuing same as above.
214	-32.0	+0.9	-	0	No. 1 - Slab split in two along longitudinal axis, stop test. No. 2 - No action.
300	-	+0.9	-	0	No. 2 - No measurable or visual change.

NOTE: <sup>1/</sup> Slabs were placed in 1/4 inch of water and cycled from 0 to 40F at rate of 12 cycles per day.

<sup>2/</sup> Plus means weight or height increase, minus means loss.

## EXHIBIT 5

### APPLICABLE SPECIAL AND TECHNICAL PROVISIONS OF THE REPAIR CONTRACT

<u>Item</u>	<u>Description</u>
1	Specification "Special Provisions," Pages SP-1 and SP-13
2	Specification Section 1A, "Environmental Provisions," Pages 1A-1 thru 1A-2
3	Specification Section 1B "Supplemental Requirements," Pages 1B-1 thru 1B-5
4	Specification Section 1C, "Measurement and Payments," Page 1C-1
5	Specification Section 3A, "Surface Coating," Pages 3A-1 thru 3A-12

SPECIFICATIONS

PART 1

SPECIAL PROVISIONS

SP-1. COMMENCEMENT, PROSECUTION, AND COMPLETION OF WORK (1965 JAN). The Contractor will be required to commence work under this contract within 10 calendar days after the date of receipt by him of notice to proceed, to prosecute said work diligently, and to complete the entire work ready for use not later than the time limits specified hereinafter. The time stated for completion shall include the final cleanup of the premises. (DAR 7-602.44)

SP-1.1 The Contractor shall complete all surface coating and painting work by not later than 1200 hours 03 April 1980.

SP-1.2 The Contractor shall complete all remaining cleanup and demobilization work by not later than 18 April 1980.

SP-1.3 Limited Work Period. The maintenance and operation of the navigation lock shall take precedence over all contract work, and nothing shall be done by the Contractor, his sub-contractors or employees which will hinder, interfere or prevent operation of the navigation lock, except during the two lock closure periods scheduled as follows:

(1) A 24-hour lock closure period on 10 March 1980.

(2) A 3-week lock closure period from 0100 hours, 16 March 1980 to 2400 hours, 05 April 1980.

If requested by the Contractor, the lock will be unwatered below tailwater level by Government personnel, except for minor leakage so that the area inside the lock will be available for required work by 18 March 1980. All Contractor materials and equipment, other than floating plant, shall be removed from inside the lock by 2400 hours 04 April 1980.

SP-1.4 Other Restrictions and Concurrent Work. Work areas and scheduled restrictions and limitations due to the presently anticipated schedule of work to be performed in these areas, to others shall be considered by the Contractor in scheduling work to be performed in accordance with the above completion dates.

SP-1.4.1 Modify Gate Seals. The seals on the navigation lock upstream gate will be modified by Government personnel during the scheduled 3-week lock closure period. Use of the upstream gate for the Contractor's operations will not be allowed during the 3-week lock closure period; however, the downstream gate will be operated by Government personnel for the Contractor's convenience. When the floating bulkhead is set into place, to facilitate lowering the lock water level below tailwater level, the downstream gate will not be operated for the Contractor's convenience.

SP-2. and SP-3. DELETED.

R1, 79DEC18

SP-28. PAYMENT FOR MOBILIZATION AND PREPARATORY WORK, PAYMENT ITEM NO. 1 (1979 MAR)

SP-28.1 Payments will be made under this contract on the actual expenditures made by the Contractor for mobilization and preparatory work under payment Item No. 1 as follows: The Contractor may submit to the Contracting Officer certified accounts of the actual payments made by him for construction plant exceeding \$10,000 in value per unit, as appraised by the Contracting Officer at the site of the work, acquired for the execution of the work; for the transportation of all plant and equipment to the site; for material purchased for the prosecution of the contract, but not to be incorporated in the work; for construction of camps, access roads or railroads, trailer courts, mess halls, dormitories or living quarters, field headquarters facilities and construction yards, and for personal services and hire of plant on work preparatory to commencing actual work on the construction items for which payment is provided under the terms of the contract. Accounts so submitted must be accompanied by certificate of the Contractor, supported by receipted bills or certified copies of payrolls and freight bills, showing that he has acquired said construction plant and material free from all encumbrances and agreement that it will not be removed from the site and that structures and facilities prepared or erected for the prosecution of the contract work will be maintained and not dismantled prior to the completion and acceptance of the entire work without the written permission of the Contracting Officer. If the Contracting Officer finds that said construction plant, material, equipment and the mobilization and preparatory work performed are suitable and necessary to the efficient prosecution of the contract and that the said preparatory work has been done with proper economy and efficiency, payment, less the prescribed retained percentage, will be made therefor to the Contractor. Payment for construction plant, material and structures and facilities prepared or erected for prosecution of the contract work shall not exceed the cost thereof to the Contractor less the estimated value upon the completion of the contract as determined by the Contracting Officer. In no event shall such payment exceed 100 percent of the cost to the Contractor of any such items which have no appreciable salvage value and 75 percent of the cost to the Contractor of such items which have an appreciable salvage value. The findings of the Contracting Officer as to the suitability and value of the construction plant, equipment, materials, structures or facilities shall not be subject to appeal.

SP-28.2 Payments for mobilization and preparatory work will be made in accordance with SP-28.1 above, and such payments will be deducted from the contract price for Item No. 1, "Mobilization and preparatory work," until the total amount thus charged to this item reduces this item to zero, after which no further payments will be made under this item. If the total of such payments made does not reduce this item to zero, the balance will be paid to the Contractor in the final payment under the contract. The retained percentage will be paid in accordance with the clause of this contract entitled "Payments to Contractor."

PART IV

TECHNICAL PROVISIONS

SECTION 1A

ENVIRONMENTAL PROTECTION

1. SCOPE.

The work covered by this section consists of furnishing all labor, materials and equipment and performing all work required for the protection of the environment during construction operations except for those measures set forth in other TECHNICAL PROVISIONS of these specifications.

2. REFERENCE.

"Standard Methods for the Examination of water and waste water," Fourteenth Edition, 1975, published by American Public Health Association, 1015 Eighteenth Street, N.W., Washington, D.C. 20036.

3. GENERAL.

For the purpose of this specification, environment protection is defined as the retention of the environment in its natural state to the greatest possible extent during project construction and to enhance the natural appearance in its final condition. Environment protection requires consideration of air, water, and land, and involves noise, solid-waste management and management of radiant energy and radioactive materials, as well as other pollutants. In order to prevent, and to provide for abatement and control of, any environmental pollution arising from the construction activities, the Contractor and his subcontractors in the performance of this contract, shall comply with all applicable Federal, State, and local laws, and regulations concerning environmental pollution control and abatement.

4. NOTIFICATION.

The Contracting Officer will notify the Contractor in writing of any noncompliance with the aforementioned Federal, State, or local laws or regulations. Such notice, when delivered to the Contractor or his authorized representative at the site of the work, shall be deemed sufficient for the purpose. The Contractor shall, after receipt of such notice, immediately inform the Contracting Officer of proposed corrective action and take such action as may be approved. If the Contractor fails or refuses to comply promptly, the Contracting Officer may issue an order stopping all or part of the work until satisfactory corrective action has been taken. No part of the time lost due to any such stop orders shall be made the subject of a claim for extension of time or for excess costs or damages by the Contractor.

5. SUBCONTRACTORS.

Compliance with the provisions of this section by subcontractors will be the responsibility of the Contractor.

6. IMPLEMENTATION.

Prior to commencement of the work the Contractor shall:

(1) Submit in writing his proposals for implementing this section for environment protection.

(2) Meet with representatives of the Contracting Officer to develop mutual understandings relative to compliance with this provision and administration of the environment protection program. Approval of the Contractor's plan for environment protection will not relieve the Contractor of his responsibility for adequate and continuing control of pollutants.

## 7. PROTECTION OF LAND RESOURCES.

The land resources within the project boundaries and outside the limits of permanent work performed under this contract shall be preserved in their present condition or be restored to a condition after completion of construction that will appear to be natural and not detract from the appearance of the project. The Contractor shall confine his construction activities to areas defined by the plans or specifications.

## 8. PROTECTION OF WATER RESOURCES.

8.1 General. The Contractor shall not pollute streams, lakes or reservoirs with fuels, oils, bitumens, calcium chloride, acids, herbicides, insecticides, or other harmful material. The Contractor shall investigate and comply with all applicable Federal, State, County and Municipal laws concerning pollution of surface or subsurface waters.

8.2 Spillages. Special measures shall be taken to prevent chemicals, fuels, oils, greases, bituminous materials, waste washings, sewage, chlorinated solutions, herbicides and insecticides, and cement and concrete drainage from entering surface and subsurface waters.

8.3 Disposal of any materials, wastes, effluents, trash, garbage, oil, grease, chemicals, etc., in areas adjacent to streams will not be permitted. If any waste material is dumped in unauthorized areas, the Contractor shall remove the material and restore the area to the original condition before being disturbed. If necessary, contaminated ground shall be excavated, disposed of as directed by the Contracting Officer, and replaced with suitable fill material, compacted and finished with topsoil and planted as required to reestablish vegetation.

## 9. PROTECTION OF FISH AND WILDLIFE.

The Contractor shall at all times perform all work and take such steps required to minimize interference with or disturbance to fish and wildlife. The Contractor will not be permitted to alter waterflows or otherwise disturb native habitat adjacent to the project areas which, in the opinion of the Contracting Officer, are critical to fish or wildlife.

## 10. BURNING.

No burning will be permitted.

## 11. MAINTENANCE OF POLLUTION CONTROL FACILITIES DURING CONSTRUCTION.

During the life of this contract the Contractor shall maintain all facilities constructed for pollution control under this contract as long as the operations creating the particular pollutant are being carried out or until the material concerned has become stabilized to the extent that pollution is no longer being created.

## 12. QUALITY CONTROL AND COMPLIANCE.

The Contractor's quality control system and the detailed plans submitted in SPECIAL PROVISIONS shall include abatement of environmental pollution, disposal of debris and wastes, control of dust, and other appropriate measures to effect compliance with the provisions of this section. The Contractor's quality control organization shall participate in required job training courses on environment protection. Deficiencies or noncompliance as noted by the Contracting Officer's Representative will be administered in accord with the procedures specified. Recurring deficiencies in abatement of environmental impacts will also be considered adequate reason for removal and replacement of ineffective quality control personnel including job supervisory staff and the top resident project manager.

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TECHNICAL PROVISIONS  
SECTION 16  
SUPPLEMENTARY REQUIREMENTS

1. GENERAL.

The work covered by this section of the specifications consists of work common to more than one section of these TECHNICAL PROVISIONS. When used in these specifications or in referenced publications, "Engineer," is synonymous with "Contracting Officer."

2. PLANT AND EQUIPMENT LIST.

In addition to the requirements of Standard Form 22 for a list of plant and equipment proposed for bidding, the Contractor shall furnish a complete list of all plant and equipment, exclusive of shop equipment, to be used on the project, in duplicate, within 30 days after date of receipt of notice to proceed. The Contractor shall submit as part of his end-of-the-month request for payment, up-to-date plant and equipment lists throughout the life of the contract. Lists shall include rented equipment as well as lease-purchase or sale-leaseback equipment. The initial list and the revised monthly lists shall indicate dates equipment is assigned to or removed from the project, dates deadline for repairs and returned for use, and adequate identification or description of each item of equipment including manufacturer's name (abbreviated), model number, manufacturer's serial number, and Contractor's assigned serial or record number.

3. HAUL ROADS AND ACCESS ROADS.

3.1 Protection and Restoration of Existing Facilities.

The Contractor shall protect all existing facilities owned by the Government and other contractors, whether or not shown on the drawings, during the life of this contract. Upon completion of the work, all the existing facilities not included as a portion of the work shall be left in a condition equal to the original condition prior to the contract. Costs for maintenance, repair and restoration of any facilities shall be considered to be incidental to and included in the bidding schedule prices.

3.2 Existing Access Roads.

For work areas at the navigation lock deck, existing access roads shall be kept open to traffic at all times. The Contractor is responsible for control of traffic, barricades, signs, and flagmen as approved by the Contracting Officer.

4. LOCATION OF CONTRACTOR'S OFFICE AND PARKING OF PRIVATE VEHICLES.

The Contractor's jobsite office or offices shall be located so that people visiting the Contractor, such as salesmen or personnel seeking employment will not have to enter the work area to get to the office. No parking of private vehicles shall be permitted in the working areas except as otherwise approved by the Contracting Officer.

5. IDENTIFICATION OF VEHICLES.

In order to keep proper control of vehicles in the work area, all Contractor's vehicles shall display suitable permanent identification.

3

6. EXISTING SANITATION FACILITIES.

Sanitation facilities shall be furnished by the Contractor in accordance with EM 385-1-1. Existing public toilet facilities will not be available for use by Contractor personnel.

7. PAYROLLS AND APPRENTICESHIPS.

Attention is directed to CLAUSE: PAYROLLS AND BASIC RECORDS of the GENERAL PROVISIONS. This paragraph requires weekly submittal of all payrolls for prime Contractor and subcontractors. It is to be noted that the address and Social Security Number of each person is to be included with the first submittal of the worker's name on the payroll.

8. PURCHASE ORDERS.

Three legible copies of all purchase orders for materials incorporated into the work showing firm names and addresses and list of materials shall be furnished the Contracting Officer as soon as issued, and immediate notice shall be given him of receipt of any material for the work, together with detailed lists of the same. Orders shall contain the contract number, applicable bid item number, and the piece mark number of the item being purchased. Purchase orders shall include the name and address of the manufacturer and fabrication site.

9. UTILITIES.

9.1 Water.

No Government-furnished water is available.

9.2 Electricity.

All reasonably required amounts of electric power will be made available to the Contractor by the Government from the Government-owned or -operated electrical systems at the project and will be supplied without cost to the Contractor. Power is available from existing 480-volt, 3-phase, 30-ampere (maximum) receptacles located at ends of the navigation lock upper deck and from 120-volt, 15-ampere receptacles located at intervals on the navigation lock upper deck. All temporary connections shall be subject to the approval of the Contracting Officer. All electricity shall be carefully conserved. If, for any reason, the Government is unable to furnish all reasonable amounts of electric power required by the Contractor in the performance of this contract, it shall be the responsibility of the Contractor to provide an adequate supply of electric power at his own expense, subject to reimbursement by the Government on an actual cost basis for the power used. No separate payment will be made for the cost of labor or materials furnished by the Contractor for installation of such alternate power supply. The location of all powerlines and all temporary connections for electricity shall be subject to the approval of the Contracting Officer. All temporary circuits and devices shall be furnished, installed, connected and maintained by the Contractor in a workmanlike manner, and shall be removed by the Contractor in like manner at his expense prior to final acceptance by the Government.

9.3 Compressed Air.

No Government-furnished compressed air is available.

10. TEMPORARY ELECTRICAL WIRING.

The following requirements for temporary electrical wiring supplement are those noted in Section XV of GENERAL SAFETY REQUIREMENTS, EM 385-1-1. Single-conductor wires such as Types WP, K, KM, I, and IN will not be installed unprotected along the ground or walkways or within reach of persons on ground or walkways. These wires shall either be protected by conduit (except Type WP) or be supported by insulators beyond the reach of persons. These wire types are not acceptable for festoon lighting and shall not be used with insulation piercing sockets. For festoon lighting the use of 2-conductor No. 12 neoprene brewery cord is acceptable provided



that where the cord is suspended, the use of wedge-type strain clamps, such as "Kellipie" Type KM is used to take the strain. Type S, SU, or SI ("Tirex") shall be used where cords are subject to extreme conditions such as rocky ground, vehicle traffic, frequent moves along the ground, and frequent exposure to moisture. Nonmetallic sheathed cable and service entrance cable shall not be used as portable cord run along the ground or suspended in the air. When exposed they shall be run against and fastened to continuous protective surfaces. Type NM (indoor) nonmetallic sheathed cable shall not be exposed to moisture. Type NML or service cable shall be used for outdoor installation and boxes used therewith shall be made of insulating material. Cabinets or cutout boxes installed where exposed to moisture shall either be painted or shall be protected from moisture. Boxes and cabinets shall not have wires and cables passing through sharp-edged holes. Individual wires shall enter boxes in conduit or through holes bushed with insulating material. Cables shall enter boxes through bushings or box connectors. All metal which encloses live electrical conductors shall be grounded with the exception of isolated fixed boxes in dry locations and so placed that persons cannot touch the box and simultaneously touch or be standing on the ground, concrete or a grounded metal surface. The term "enclosure" includes safety-switch and motor-started boxes, panelboard enclosures, switch and outlet boxes, and the frames of portable power tools. Metal stands for portable floodlights also shall be grounded. Water-pipe grounds shall be used whenever possible. All "made" grounds shall provide a maximum ground resistance of 25 ohms. Ground wire connections shall utilize clamps or lugs so as to provide a mechanically sound, low-resistance connection. Ground wires shall be of the size specified by the N.E.C. and shall be run or protected to avoid injury. If subject to flexing or vibration, the ground wire shall be stranded. Grounding of portable electrical equipment including floodlight stands shall be accomplished by means of an extra conductor within the cord and an additional contact on the receptacle plug so arranged that the circuit and ground conductors cannot be interchanged. The neutral conductor shall not be used as the ground conductor. Mechanical protection and stranding of the ground conductor shall be equal to that of the circuit conductors. If a Contractor's portable equipment has plug caps which will not match receptacles equipped with a grounding connection, he shall replace the cord and plug to the proper type and permanently connect ground wire to equipment case. Ground wires in portable cords shall always be identified by a green color and neutral conductors shall be white or gray. Special care shall be exercised in making up portable cords to be sure that the circuit and ground conductors are not interchanged. The frames of all portable engine-generator plants shall be grounded. This will usually entail a driven ground adjacent to the machine. The neutral wire of plants having an output voltage of 115-230 volts three-wire also shall be grounded. All ungrounded conductors shall be protected by fuses or circuit breakers of no higher ampere rating than allowed by the N.E.C. The Contractor shall provide and maintain in use on the site a suitable ground testing device and authorized quality control personnel shall perform tests initially and subsequently whenever temporary wiring is altered to assure the adequacy of "man-made" grounds. Welding machine leads shall be kept free of bare spots and splices shall be made using standard insulating splicing devices made for the purpose. Every motor shall have a disconnecting means in sight of the controller location or arranged to be locked in the open position. Work on all temporary electrical wiring shall be performed only by qualified journeymen electricians. Temporary electrical wiring shall be considered as incidental to the work and no separate payment will be made therefor.

#### 11. WORK AREA.

Contractor's material storage, work and parking areas shall be as approved by the Contracting Officer and as indicated on the drawings.

#### 12. USE OF POWERHOUSE INTAKE DECK, SPILLWAY BRIDGE, AND NAVIGATION LOCK BRIDGE AND ROADWAY.

The powerhouse intake deck, spillway bridge, and the navigation lock deck and bridge may be used for limited access to the work area with Contractor vehicles only. Hauling of materials and transporting of men and equipment will be permitted on this roadway subject to a load limitation equivalent to the Standard Highway HS20 loading. The Contractor shall protect the various portions of the structures from damage by traffic, prevent material from falling through the deck openings, and also keep the areas in use cleaned up and orderly at all times during use. Vehicle speeds, special precautions, and safety measures shall be as directed by the Contracting Officer.

EXHIBIT 5

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ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG--ETC F/G 13/2  
DETERIORATION AND REPAIR OF CONCRETE IN THE LOWER MONUMENTAL NA--ETC(U)  
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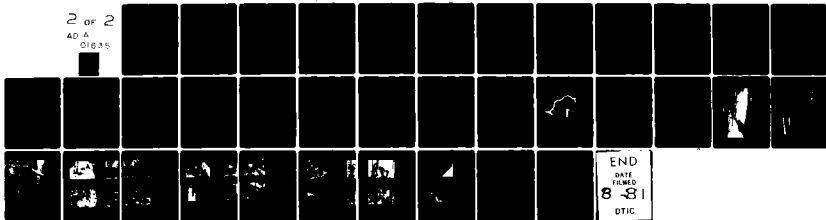
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13. DAILY CLEANUP.

All debris resulting from the work, such as packing cases, cement bags, scrap lumber and other debris shall be collected and removed from the work area daily and disposed of off project land. All costs of removing debris shall be incidental to the work, and no separate payment will be made therefor.

14. DISPOSAL OF WASTE MATERIALS.

Collection and disposal of all waste materials shall be performed in a manner and with such necessary scaffolding, nets, and collection facilities and equipment as to prevent any accidental or deliberate disposal of materials in the lock chamber or in any water area at the dam. All floating plant used for storage and hauling of debris and waste materials from construction operations shall have containment walls a minimum of 4 feet in height and of minimum 3-inch timbers rigidly installed surrounding the debris collection area. Concrete materials and any sandblasting sand collected during surface preparations and surface coating applications shall be disposed of at the waste disposal site indicated on the drawings.

15. ILLUMINATION.

The Contractor shall furnish all plant, equipment, labor and materials, excepting Government-furnished electricity and area flood lighting, to insure adequate illumination for operations in accordance with the provisions of Section 14 of EM 385-1-1, GENERAL SAFETY REQUIREMENTS. The term "adequate illumination" as used herein, shall be construed as the minimum lighting required to provide safe working conditions and provide sufficient light to permit the work to be performed in accordance with the plans and specifications and to permit complete inspection of all work. No direct payment will be made for providing such illumination and the cost thereof shall be considered as incidental to and included in the contract lump sum price.

16. WORK AREA ACCESS.

The Contractor shall submit for approval, any scaffolding, ladder, stairway or other access schemes he proposes to use, including type, layout, and connections. Approved anti-slip surface material shall be installed on scaffolding platforms. Scaffolding shall comply in every respect with EM 385-1-1, GENERAL SAFETY REQUIREMENTS. The Contracting Officer's approval will not be considered to relieve the Contractor of any responsibility for compliance with the contract and applicable State laws. The Contractor shall provide access to the work area in the lock chamber for the Contracting Officer or any inspector at all times.

17. LOCK OPERATIONS AND CLOSURE PERIODS.

The Government will maintain lock operations throughout the contract period, except during the 24-hour and the 3-week lock closure periods specified in Paragraph SP-1.3 of the SPECIAL PROVISIONS. The Contractor will be given approximately 1 hour advance notice of lockages to allow removal of equipment and personnel from the lock chamber and to perform any necessary operations to allow interruption of the Contractor's work operations so lockages may be performed. The average time for a lockage from arrival of a boat at the lock entrance and completion of lockage is approximately 1 hour. Lockages exceeding 1 hour caused by delays due to the Contractor's operations such as splitting of tows because of the Contractor's equipment in the lock shall not be made the subject of a claim against the Government. An average of seven commercial boat lockages are made each day at Lower Monumental Lock. The water in the lock will be maintained by the Government within a range of 2 feet of the levels requested by the Contractor to facilitate his operations at any time when working in the lock chamber. The Government will vary the water level in the lock chamber at minimum intervals of 4 feet. The Contractor shall notify Government personnel at least 12 hours in advance of any need for an adjustment in water level in the lock and at least 48 hours in advance of the need to lower the water level below the tailwater level. When the water level in the lock is to be maintained at an elevation below tailwater level, the difference in water levels shall be at least 7 feet and the Contractor shall furnish personnel to operate

Government works to continuously control leakage so that the difference in water levels needed to seat the unwatering bulhead is maintained. The Government will require 24 hours to perform the work required to unwater or rewater the lock. The Contractor shall schedule his operations so that the Government will have time to perform any unwatering and rewatering of the navigation lock without extending the scheduled lock outage periods.

#### 10. WORK WITH RESTRICTIONS.

##### 10.1 Public Access Across Dam.

The Government allows and maintains access across the dam to the public using private vehicles during the following hour periods during the year:

<del>Season</del>	Hours Open to Public Access
May thru August	5 AM to 10 PM
September and October	6 AM to 8 PM
November thru February	7 AM to 5 PM
March and April	6 AM to 8 PM

The Contractor shall arrange his work schedules and operations on the navigation lock deck to maintain a clear single lane access of 4-foot width through his work areas to allow public access during the above listed public access periods and to allow access by government vehicles at all times.

10.2 ~~Mooring Buoys~~ in the lock may be used ~~only~~ for securing floating plant in place; they shall not be used for winching or moving of floating plant.

#### 11. SAFE CLEARANCE PROCEDURES.

A project-operated safe clearance procedure will be in effect during the contract period. All operation of electrical switches and mechanical valves shall be coordinated through the Contracting Officer's Representative with the dam operations office.

#### 12. COMMUNICATIONS.

The Contractor shall install a satisfactory means of communication such as a telephone or other reliable communication device between the navigation lock upper deck and the work area in the lock chamber. The Contracting Officer or any inspector shall be provided use of the communication device at any time upon request.

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R1, 79DEC18

TECHNICAL PROVISIONS

SECTION 1C

MEASUREMENT AND PAYMENT

1. GENERAL. In each instance the contract price for an item shall constitute full compensation for furnishing all plant, labor, equipment, and materials and performing all operations required to complete the work included in the item as hereinafter specified, as shown on the drawings, or as otherwise approved.

2. MOBILIZATION AND PREPARATORY WORK will be measured for payment as a complete pay item (job) in accordance with paragraph SP-28 of the SPECIAL PROVISIONS. Payment will be made at the applicable contract lump-sum price for Item No. 1, "Mobilization and preparatory work," which price and payment shall be full compensation for mobilizing all necessary equipment at the site and performing any necessary preparatory work, including test panels, for performance of the concrete repair at the lock structure, as specified and approved.

3. LOCK WALL SURFACE COATING. The surface coating of the lock wall concrete surface will be measured for payment as a complete pay item (job). Payment will be made at the contract lump-sum price for Item No. 2, "Surface coating," which price and payment shall be full compensation for furnishing all required materials, equipment, and labor for installation of the specified surface coating, including surface preparation and painting stripes, all as specified and approved.

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# TECHNICAL PROVISIONS

## SECTION 3A

### SURFACE COATING

#### 1. SCOPE OF WORK.

The work covered by this section consists of furnishing all material and equipment, and performing all labor for the preparation, proportioning, and application of a shotcrete coating to the interior wall surface of the navigation lock. Common terminology that has developed refers to the specialized shotcrete coating as the "spray-on" or "spray-up" process. The coating system specified herein shall be applied to all concrete surfaces (except as noted below) of the navigation lock walls within the lock chamber, extending from the level of the roadway deck down to the construction lift joint at elevation 435.0. Shotcrete coating shall not be applied to the concrete surfaces of the upper sill, bridge upstream and downstream lift gate recesses, mooring bitt recesses, access ladder recesses, and the cable guards at monoliths 27 and 28. Initial preparation of surfaces to receive shotcrete may be performed at any time between lockages and during the scheduled lock closure periods as specified in paragraph SP-1.3 of the SPECIAL PROVISIONS. Application of the shotcrete coating shall be performed only during the above specified lock closure periods.

#### 2. GENERAL.

The lock wall surface is deteriorating through failure of the mortar portion of the concrete. This is primarily the result of freezing and thawing while the mortar is saturated. The surface coating to be applied under this contract will protect the existing concrete from further deterioration. However, the coating material shall be properly mixed and applied and shall be applied only after the existing surface has been thoroughly prepared and cleaned. Previous laboratory and field tests at Lower Monumental have demonstrated the quality and practicality of doing this work under construction contract. Proper and thorough advanced planning and preparations are an essential part of the Contractor's operations to insure that all surface coating work is completed as specified in paragraph SP-1.1 of the SPECIAL PROVISIONS because no additional work time will be allowed. A detailed and extensive report concerning test results and observations made during application of the material to a trial area under a construction contract during 1978 has been prepared for the Government by a consultant. It includes photographs, details of production rates, problems with various construction techniques, etc. This report is available (one per bidder) upon written request.

#### 3. CONDUCT OF WORK.

##### 3.1 Plan of Operation.

Within 10 days after the date of receipt by him of notice to proceed, the Contractor shall submit for review a detailed plan of operation. At a minimum the plan shall include the number and size of crews, hours per shift and number of shifts, type and layout of plant and equipment and sequence of operation for both surface preparation and application of surface coating.

##### 3.2 Work Schedule.

The Contractor shall submit a complete work schedule of proposed work progress by not later than 10 days after receipt by him of notice to proceed. The work schedule shall be prepared and submitted in accordance with CLAUSE I PROGRESS CHARTS AND REQUIREMENTS FOR OVERTIME WORK of the GENERAL PROVISIONS and shall be in the form of a bar chart or critical path. As a minimum the schedule shall identify major items of work, show duration and dates of work items, show float time, and indicate any interaction with Government work being performed during the contract period. The schedule shall include the items of work listed below under paragraph Sequence of Work.

### 3.3 Sequence of Work.

The Contractor shall schedule his operations in accordance with the following sequence of work. The work sequence given below is intended to verify to the Government that the Contractor will be ready to perform the surface preparation and coating application during the scheduled lock closure periods.

(1) Test Panels. At least 10 days prior to the scheduled 24-hour lock closure period on 10 March, the Contractor shall demonstrate his methods of surface preparation as specified in paragraph Field Demonstration and construct spray-up test panels as specified in paragraph Spray-Up Test Panels - Para 9.1.2.

(2) Coating Application Above Elevation 545.0. During the 24-hour lock closure period on 10 March the Contractor shall perform surface preparation and apply fiberglass fiber reinforced spray-up coating material to the interior lock walls between the construction lift joints at elevation 545.0 and the roadway deck level. This work shall be a full scale test of the Contractor's plan of operation. Work not completed during this time shall be completed during the 3-week lock closure period.

(3) Coating Application Below Elevation 545.0. All required spray-up coating applications on the interior lock walls shall be performed during the 3-week lock closure period as specified in paragraph SP-1.3 of the SPECIAL PROVISIONS.

### 4. APPLICABLE PUBLICATIONS.

The following publications of the issues listed below, but referred to thereafter by basic designation only, form a part of this specification to the extent indicated by the references thereto:

(1) American Concrete Institute (ACI).

ACI 506-66 Recommended Practice for Shotcreting.

(2) American Society for Testing and Materials (ASTM).

C 150-78a Portland Cement.

C 173-78 Air Content of Freshly Mixed Concrete by the Volumetric Method.

C 231-78 Air Content of Freshly Mixed Concrete by the Pressure Method.

C 494-79 Chemical Admixtures for Concrete.

C 685-78 Concrete made by Volumetric Batching and Continuous Mixing.

### 5. MATERIALS.

#### 5.1 General.

All required quantities of the specified, approved materials as required to perform the complete spray-up coating work shall be on the jobsite prior to 10 March. Due to the lead time required for manufacturing and transporting of the hereinafter specified latex and fiberglass materials, the Contractor shall submit purchase orders to the Contracting Officer indicating that these materials were ordered within 5 days after receipt by him of notice to proceed. Materials shall be protected at all times to prevent damage, contamination, and freezing.

#### 5.2 Cement.

Cement shall conform to ASTM C 150, Type I or II, low alkali, including false start requirements. The Contractor shall provide suitable cement certificates showing that the chemical and physical properties of cement delivered to the jobsite meet specified requirements. The temperature of the cement shall be below 150 degrees F. at the time it is used. Cement shall be used within 6 months of the

date of manufacture. Cement that has been exposed to moisture, contains lumps, or that is shipped to the job site in opened packages shall be removed from the project and not used in this work.

### 5.3 Admixtures.

Admixtures shall conform to ASTM C 494, Type B or Type D. Air-entraining admixtures and accelerators shall not be used. It shall be the Contractor's responsibility to be certain that any admixtures used shall be compatible with the cement and latex.

### 5.4 Water.

Water shall be clean and free from injurious chemicals. Potable water may be used.

### 5.5 Latex.

Latex shall be "Saran Cement Modifier 3H" formulation containing approximately 50 percent solids with an antifoaming additive available from Dow Chemical with a sales office in Bellevue, WA, Telephone: (206)455-7250, Mr. Doug Heed. No substitution for the latex material will be allowed. Several years of extensive and time consuming tests have already been conducted on mixes containing latex formulations equivalent to the one specified, and the Government would require more time than the contract period allows in order to approve a substitute material.

### 5.6 Fiberglass Fibers.

Fibers shall be single-strand, multiple-filament, alkali-resistant fiberglass for use in cement coatings as produced by Owens Corning Fiberglass Company, Fiberglass Tower, Toledo, OH 43659, telephone: (419)248-8832, Mr. M. J. Molloy. The fiber length for the spray-up coating shall be approximately 3 to 4 inches. No substitution for the fibers will be allowed. The Government has already conducted several years of long and extensive tests with mixes using the specified fibers, and more time than the contract period allows would be required for approval of a substitute material. Acquisition of this material is subject to conditions imposed by Owens Corning. It shall be the Contractor's responsibility to satisfy the conditions of purchase of this material.

### 5.7 Aggregate.

Only fine aggregate will be used for the shotcrete mix. The aggregate shall be obtained from the Government-owned stockpile just upstream of the dam at the location indicated on the drawings. The aggregate is 100 percent manufactured and washed material produced from larger gravels and stockpiles several years ago. Typical gradations of the stockpiled material as they were tested last year and used in a small spray-up trial are listed at the end of this paragraph. Frozen lumps, organic material, oversized rock and other foreign material shall be removed from the aggregate before it is used. The Contractor may elect to screen off the coarser material and use only that aggregate which is finer than either the No. 4 or No. 8 sieve. The Contractor shall perform any required processing of Government-furnished aggregate prior to the start of spray-up coating application. Subject to approval by the Contracting Officer's Representative, the Contractor may substitute for the Government-furnished aggregate a prepackaged silica sand typically used in spray-up coating applications and furnished by an established supplier.

#### TYPICAL FINE AGGREGATE GRADATION FROM THE GOVERNMENT STOCKPILE

<u>Sieve Designation, U. S.</u> <u>Standard Square Mesh</u>	<u>Percent by Weight, Passing</u>
3/8 in. (9.5mm)	100
No. 4 (4.75mm)	99
No. 8 (2.36mm)	88
No. 16 (1.18mm)	63
No. 30 (0.60mm)	36
No. 50 (0.30mm)	19
No. 100 (0.15mm)	9



## 6. COATING FORMULATION.

The formulation for the spray-up coating shall be as given below. Minor variations may be approved or directed by the Contracting Officer's Representative in the field to fit specific conditions existing at the time of placement. These variations are primarily intended to take into account moisture variations due to evaporation and the degree of moisture in the aggregate. They may also be used to adjust for actual specific gravities of the aggregate used and to provide the proper admixture effects. A change to different cements or a special cement such as Type III or Type K will be approved only if the quality of the finish product will be at least that which would have been achieved with the specified cement, and only if the proposed cement has demonstrated its properties and performance for the same type of applications in the past. It will be the Contractor's responsibility to document such a proposal in writing. Approval is subject to the Contracting Officer's evaluation and is not guaranteed.

### BATCH WEIGHTS (POUNDS/CUBIC YARD)

ITEM	WEIGHT
Water	245
Cement	1720
Fibers	117
Latex	520
Fine Aggregate <sup>1</sup>	860
W.M.A. <sup>2</sup> (oz)	75

NOTE: <sup>1</sup> Fine aggregate batch weights shall be adjusted for moisture and specific gravity.

<sup>2</sup> The dosage of W.M.A. may vary considerably depending on the source and concentration.

## 7. SURFACE PREPARATION.

### 7.1 General.

Prior to applying the spray-up coating, the surface shall be prepared by removing all loose, unsound, and friable material and by removing all surface contaminants such as dust, silt, old curing compound, organic growth, etc. The purpose of applying the coating is to prevent continued deterioration of the mortar portion of the concrete. Due to the deterioration that has occurred to date, much of the mortar is very poor, crumbly, and friable. All of this unsound material shall be completely removed prior to application of the coating. However, the Contractor will not be required to remove unsound material to depths greater than 1 1/2 inches from the originally formed vertical wall surface. It is expected that the average depth of removal of deteriorated material will be from 1/8 inch to 3/8 inch as measured from the existing surface. A cleaning method or combination of methods that safely and thoroughly performs this cleaning without undercutting exposed aggregate is required. The procedure used will be subject to the approval of the Contracting Officer after a field demonstration. Some possible cleaning procedures are high-pressure waterjets, air-water cutting, sandblasting, mechanical brushes, or a combination of these. In addition, some manual cleaning may be necessary with pneumatic chipping guns, bushhammers, and hand tools. Satisfactory measures shall be taken to protect the exposed surfaces of embedded metal, the painted surfaces of the lift gates, and the stiff gauges from damage caused by the Contractor's operations. If a lockage occurs between the time that surface preparation is completed and the time that the coating is to be applied, the surface shall be hosed down with wash water and the surface shall air dry past the point that there is no free surface moisture prior to application of the coating. The Contractor may do the majority of surface preparation between lockages well in advance of the shotcrete coating application date. However, a final cleaning during the lock outage period and just prior to the actual application of spray-up materials shall be necessary. Acceptance of surface preparation will be determined by the Contracting Officer's Representative at the time of application.

#### 7.1.1 Air-Water Cutting.

Air-water cutting shall be performed with an air-water jet to expose clean, sound aggregate, but not so as to undercut the edges of the larger particles of aggregate. The air pressure used in the jet shall be at least 200 p.s.i. and the water pressure shall be just sufficient to bring the water into effective influence of the air pressure. After cutting, the surface shall be washed and rinsed until there is no trace of cloudiness in the wash water. Where necessary to remove accumulated coatings, stains and debris, wet sandblasting may be required as the last operation before placing the spray-up coating.

#### 7.1.2 High-Pressure Water Jet.

A stream of water under a pressure of not less than 6,500 p.s.f. may be used for cleaning, except that if the pressure is found to cause undercutting and to remove excessive materials, the Contracting Officer's Representative will direct that the pressure be reduced. If the water jet is incapable of satisfactory cleaning and it is not undercutting aggregates, the pressure shall be increased or a supplemental method of cleaning shall also be used. The water jet equipment shall have a rated capacity of at least 10,000 p.s.f.

#### 7.1.3 Wet Sandblasting.

Wet sandblasting shall be continued until unsound material is removed and until all coatings, stains, and debris are removed. The surface of the concrete shall then be washed thoroughly to remove all loose material. Sand emitted under high pressure from blasting nozzles shall not make direct contact on any metal surfaces. Protective measures shall be taken such as covering the surfaces with plywood or other approved methods in order to comply with this requirement. Spent blasting sand shall be prevented from drifting and landing on machinery and on the grease-coated cables which operate the lift gates.

#### 7.1.4 Mechanical Cleaning.

Mechanical cleaning of the concrete surface by means of special power-driven large wire brushes or abrasers designed for that purpose will be allowed if they remove unsound material and if they remove all coatings, stains, and debris without fracturing and dislodging large aggregate. Abrading in more than one direction will probably be necessary in order to do a satisfactory job. After brushing, the surface shall be washed thoroughly to remove all loose material, dust, and debris.

#### 7.1.5 Field Demonstration.

The Contractor shall demonstrate its ability to meet specification requirements for surface preparation. The field demonstration shall be performed on a minimum 50-square foot area of existing concrete within the lock chamber that will later receive spray-up coating. The demonstration shall be performed at approximately elevation 530.0 at a location selected by the Contracting Officer's Representative. Demonstration of surface preparation shall be performed in the presence of the Contracting Officer's Representative. The Contracting Officer shall be notified at least 7 days in advance of the day the Contractor selects to perform the field demonstration so that the Government can make proper arrangements to provide the Contractor a maximum of 4 hours undisturbed use of the lock.

#### 7.1.6 Government Cleaning Experience.

The Government has observed various cleaning techniques, methods, and equipment used to remove unsound, loose, and friable materials from the deteriorated lock wall surface. These include previous contractor efforts, specific trials done under purchase order, and first-hand experience by Government personnel. The following comments are a brief summary of what has been observed. They are made for general background information only. They shall not be construed as an endorsement or disapproval of any equipment or cleaning methods. They represent an opinion based on limited experience but are offered here so that the Contractor has the benefit of all information available to the Government.

(1) Air-water cutting at low pressures (approximately 70 p.s.f.) will remove only some of the loose friable materials.

(2) Many areas have aggregates typically 1-1/2 to 3 inch in size that protrude out up to about 1/4 inch past the depth of deteriorated concrete. These are almost always tightly bonded and do not need to be removed.

(3) High-pressure water jet equipment capable of pressures up to 10,000 p.s.i. can remove most all of the unsound friable materials. The majority of it comes off very readily.

(4) Light sandblasting was relatively ineffective in removing all necessary material.

(5) Air-operated wire-brushing equipment easily powers out when pressed tightly enough to the wall to gouge between exposed aggregate. It is suitable for buffing off dried algae, and surface contaminants.

(6) The rotary type of hand-held and air-operated mechanical abrader removes unsound materials satisfactorily if enough air is available to power it, and until large aggregate is exposed. It is difficult to work over large aggregate pieces to effectively remove unsound materials between them.

(7) Unsound materials can often be pried, chipped, or picked off of the surface in about the lower two-thirds of the lock wall using chisels, screwdrivers, and hammers. Sometimes the material can be peeled off with bare hand and fingers. It typically will fall off in pieces about 1/8 to 1/4 inch thick and 1/2- to 15-square inches in area. Exposed large aggregate is left behind. Additional cleaning between the aggregate is sometimes necessary.

## 7.2 Existing Shotcrete Coatings.

### 7.2.1 Monolith 9.

The surface of monolith 9 has been coated with various types of spray-up coatings under a previous contract. Portions of these coatings have become separated from the lock wall and shall be removed before the new coating is applied. The surface of monolith 9 was divided into six equal width test panels. Two of the panels were constructed of conventional shotcrete. Four of the test panels were constructed of fiberglass reinforced shotcrete (two with latex additive). It may be difficult to remove the loose portions of these coatings. The materials have high-flexural strength and toughness. Even though they could be totally debonded in some areas, they will hold tightly to the bonded material surrounding them. All unbonded material shall be removed and the bonded material may remain in place. After removal of the unbonded coating areas, the entire surface of monolith 9 shall be cleaned and coated with the spray-up material.

### 7.2.2 Existing Spray-Up Coating Panels.

The existing spray-up panels on monolith 9 have been core drilled at 24 locations. The core holes are 3 inches in diameter and 6 to 10 inches in depth and shall be cleaned and filled by dry-packing with an approved mixture before the area is coated with the spray-up material.

## 7.3 Prestress Cover Protection.

Concrete, grout, and/or epoxy mortar patches cover the ends of prestressing rods installed in monoliths 5 and 6. A contract in 1978 repaired most of the deteriorated patches by removing unsound material and sealing or replacing them with epoxy mortar. All unsound material shall be removed from deteriorating patches. When the removal of unsound material exceeds 1 inch in depth they shall be built back with dry pack, shotcrete, or an approved epoxy mortar. Photographs on the drawings show the patches.

## 7.4 Existing Paint Stripes.

A yellow strip of epoxy paint is located on both ends of the interior face of the lock's south wall. The 6-foot wide vertical stripes extend from the top of the parapet wall to tailwater level. The portion of the painted stripes below the level of the roadway deck shall receive surface preparation as specified for concrete surfaces and all loose paint and paint bonded to unsound material shall be removed. Paint which is tightly bonded to sound material may remain in place and the spray-up

coating material shall be applied over it. Stripes shall be repainted as specified in paragraph: REPLACE PAINT STRIPES.

#### 7.5 Debris Disposal.

Waste and wash water from surface preparations of the lock wall shall be controlled to minimize the amount of material that enters the lock chamber. The Contractor shall provide a catch or trough at the base of the area being cleaned to trap material being removed, waste water, and sand from sandblasting operations. The trough shall extend out into the lock chamber at least 6 feet from the lock face, shall have at least 2 feet of freeboard above the top of debris accumulations in it, shall provide for drainage through a screen for any wash water, and shall extend at least 6 feet in the upstream and downstream directions past the area being cleaned. Collected debris shall be disposed of at the waste disposal area indicated on the drawings.

### 8. APPLICATION OF SPRAY-UP MATERIALS.

#### 8.1 Preparation.

The surfaces to receive spray-up coatings shall be prepared as specified in paragraph: SURFACE PREPARATION. The prepared areas shall be coated with the required spray-up system within 4 weeks after its preparation. In addition, if the prepared surface has gone through a lockage since final wash down after completion of the preparation, it shall be rewash prior to the application. The surface shall be drained and without visible free surface water at the time the coatings are applied. A "saturated surface dry condition" or drier is required. Blowing with compressed air to facilitate drying may be required to obtain this condition. The surface to receive the spray-up coating shall not have been inundated by water in the lock within 8 hours prior to applying the coating.

#### 8.2 Available Expertise.

The use of fiberglass fibers in "spray-up" applications is relatively new, but, it is an accepted, common, and standard procedure in some parts of the country. The addition of latex to the process is one further refinement. Two sources of information concerning the process and its application are: (1) Bud Molloy, Reinforced Cement Marketing Division, Owens Corning Fiberglass, Fiberglass Tower E8, Toledo, Ohio 43059, Telephone: (419)248-8832 and (2) Glas-Con, Inc., General Contractors, 9320 James Ave. South, Minneapolis, Minnesota 55431, Telephone: (612)881-5887. These references have given permission to list their names as sources of assistance and general information. However, any exchange of information between the Contractor and these sources is strictly between the two parties and should not be construed to be a part of this contract.

#### 8.3 Batching and Mixing.

##### 8.3.1 General.

The Contractor shall provide an on-site dependable batch-type mixing plant and/or volumetric batching and continuous mixing plant. The equipment shall be capable of combining the aggregate, cement, admixture, latex, and water into a uniform mixture and of discharging this mixture without segregation. Adequate facilities shall be provided for the accurate measurement and control of each of the materials entering the shotcrete. The complete plant assembly shall include provisions to facilitate the inspection of all operations at all times. The Contractor shall have available at the jobsite any required standby equipment, spare parts, and supplies necessary to prevent breakdowns from causing excessive delays to the spray-up operations.

##### 8.3.2 Admixture.

An accurate system for measuring and dispensing the admixture shall be provided. The system shall include a device visible to the plant operator which will detect and indicate the presence or absence of flow of the admixture, or there shall be provided a convenient means for the plant operator to visually observe the admixture in the process of being batched or discharged. A graduated beaker or flask may be used to measure and batch the admixture for small (less than 4-cubic foot) batches. Admixture shall be added to the mix simultaneously with the water.

### 8.3.3 weigh batching and mixing.

\* The batching and mixing plant for shotcrete shall provide separate bins or compartments for aggregate and cement. The compartments shall be of ample size and so constructed that the materials will be maintained separated under all working conditions. Cement shall be weighed whether on a separate scale or cumulatively with the aggregate in a separate compartment attached to the aggregate weighing hopper. If cement is weighed on the same scale as the aggregates, the cement shall be weighed first and all hoppers shall be empty and the scale shall be in balance before the weighing is begun. Cement may be batched by full bags assuming that one bag equals 94 pounds. Water and latex may be measured by weight or by volume. Latex must be thoroughly mixed before and during the time any drum of it is used. If not kept agitated by thorough initial mixing and periodic stirring afterwards, the solids portion and anti-foaming agent may separate from the water in the blend. If measured by weight it shall not be weighed cumulatively with any other ingredient. The plant shall be arranged to facilitate the inspection of all operations at all times. Facilities shall be provided for readily obtaining representative samples of aggregate from each of the bins or compartments. Delivery of materials from the batching equipment shall be within the following limits of accuracy for each material:

Material	Percent by Weight
Cement	4
Water	4
Aggregate	6
Admixture	6
Latex	4
Fibers	7

### 8.3.4 Volumetric Batching and Mixing.

If volume proportioning plant is employed, devices such as counters, calibrated gate openings, and/or flow meters shall be available for controlling and determining the quantities of the ingredients discharged. In operation, the entire measuring and dispensing mechanism must produce the specified proportions of each ingredient. All indicating devices that bear on the accuracy of proportioning and mixing of shotcrete shall be in full view and near enough to be read by the operator while concrete is being produced. The operator shall have convenient access to all controls. The proportioning and indicating devices shall be individually checked by following the equipment manufacturer's recommendations as related to each individual shotcrete batching and mixing unit. Adequate standard volume measures, scales, and weights shall be made available for checking the accuracy of the proportioning mechanism. Tolerances for volumetric batching shall be the same as they are for weigh batching. Continuous mixers shall be an auger-type mixer or any other type suitable for mixing shotcrete of the mix proportions given to meet the required consistency and uniformity requirements. Each batching or mixing unit, or both, shall carry in a prominent place a metal plate or plates on which are plainly marked the gross volume of the unit in terms of mixed shotcrete, discharge speed, and the weight-calibrated constant of the machine in terms of a revolution counter or other output indicator. The mixer shall produce a thoroughly mixed and uniform shotcrete. The batcher-mixer unit shall contain in separate compartments all the necessary ingredients needed for the manufacture of the shotcrete. The unit shall be equipped with calibrated proportioning devices to vary the mix proportions.

### 8.3.5 Batching Fibers.

Fibers of different types have been successfully added to shotcrete by a number of different techniques. The Government has had experience in these procedures. The actual procedure used shall be determined by the Contractor and shall be his responsibility. The procedure used shall be satisfactorily demonstrated in the field before approval for production operations is granted. Fibers for the spray-up process have been successfully added at the nozzle by chopping them from a reel of continuous strand while simultaneously spraying the mortar. Procedures for fiber addition at the nozzle shall be such that the fibers are uniformly distributed throughout the mortar matrix without isolated concentrations or holidays. If the Contractor proposes to add the fibers to a dry or wet mix during the batching and mixing or delivery process, the Contractor must devise equipment and techniques that will prevent any fiber clumps from entering the lines and must prevent the individual

filaments of the fiberglass strands from separating. Fibers shall not be added to any dry or wet mix at a rate faster than they can be blended with the other ingredients without forming tails or clumps. Bulk fibers that have a tendency to tangle together shall pass through a distributor or be carefully sifted into the mix so that they enter it as individual elements and not as clumps. Difficulties have been encountered in the past when attempting to add fiberglass fibers into a conventional shotcrete process.

#### 6.3.6 Wet Mix/Delivery Process.

Accumulations of lumps and hardened materials in the mixing and delivery equipment will not be permitted. After completion of mixing, the mix shall be metered into a delivery hose and conveyed by compressed air or a pump to the nozzle. The compressor or pump shall be capable of providing sufficient nozzle velocity for adequate compaction of the shotcrete at all elevations of operation that may be required, when necessary a blow-by pipe shall be provided for cleaning the surface and cleaning away rebound.

#### 6.3.7 Dry Mix/Delivery Process.

Accumulations of hardened materials in the mixing and delivery equipment will not be permitted. The moisture content of the sand shall be such that clumping of the "dry" mix does not occur and so that the mix will flow through the delivery hose at a uniform rate without slugs. Dry-mix delivery equipment shall be of design and size which has given good results in similar work. It shall be capable of delivering the premixed materials accurately, uniformly and continuously through the delivery hose at a velocity of 300 to 400 feet per second. The discharge nozzle shall be equipped with a manually operated water injection system (water ring) for directing an even distribution of water through the delivered mixture. The water nozzle shall be capable of ready adjustment. The air compressor shall be capable of maintaining a supply of clean, dry air adequate for maintaining sufficient nozzle velocity for all parts of the work and for the simultaneous operation of a blow pipe for cleaning away rebound. Application of fiberglass reinforced shotcrete through the dry mix process has, at best, had marginal success in the past. Use of latex in the mix further complicates the problem. It could be handled through a separate "water" ring at the nozzle. Despite past difficulties with this method of application for glass-fiber mixes, it can be much faster and more economical than the spray-up method. Therefore, if the Contractor can adequately demonstrate a special dry-mix delivery method that can evenly mix and apply the specified coating formulation and obtain the same quality results as the standard method of application the Contracting Officer will approve its use.

### 4. APPLICATION.

#### 4.1 Personnel.

##### 4.1.1 Qualification.

The spray-up coating shall be placed only by operators skilled in this type of work using the same kind of equipment to be used by the Contractor. Each foreman shall have had at least 2 years experience as a shotcrete nozzleman. At least two of the nozzlemen shall have served at least 6 months apprenticeship on similar applications with the same type of equipment to be used. All other nozzlemen shall have had at least 2 weeks of "hands-on" training and shall have demonstrated a skill in application. At least 5 days prior to construction of test panels the Contractor shall submit written documentation indicating where and when each nozzleman and foreman obtained his experience and training in applying coatings similar to the spray-up coating specified herein.

##### 4.1.2 Spray-Up Test Panels.

Each spray-up placing crew shall demonstrate their ability to perform satisfactorily and to apply coatings of the required quality by placement of test panels. The test panels will be evaluated by the Government on the basis of relative strength, thickness, fiber distribution, etc. One satisfactory test panel shot in a vertical position shall be the minimum qualification test for each crew before it is permitted to apply spray-up coatings in permanent construction. The test panel

placement shall be made against a plywood surface at least 9-square feet in area provided by the Contractor. All test panels shall be made in the presence of the Contracting Officer's Representative.

## 9.2 Shotcrete Application.

### 9.2.1 General.

The spray-up coating shall be applied by holding the nozzle at such a distance and position that the stream of flow material shall impinge as nearly as possible at right angles to the surface being covered to produce a spreading effect over a small area. The velocity of discharge from the nozzle, the distance of the nozzle from the face, and the amount of water used shall be regulated to produce a dense coating, without sloughing. The work platform from which the crew is applying the coating shall be wide enough to allow the nozzle to be held the proper distance from the lock well. Rebounding material shall be removed from the work area and disposed of at the waste disposal area. The coating shall have a minimum thickness of 3/8 inch measured from the lock well surface existing after surface preparation. The Contractor shall provide a method of positively demonstrating that the required thickness has been obtained and the thickness shall be continually checked during application of the coating. One method of doing this is through the use of probes stabbed into the mix immediately after application. The Government reserves the right to saw or core random areas from in-place shotcrete for testing and to verify the required thickness. An additional 3/8-inch thickness of shotcreting will be required, at no cost to the Government, for areas found to lack the required minimum thickness.

### 9.2.2 Additional Requirements for Glass-Fiber Shotcrete.

The fiberglass fiber reinforced spray-up material shall be applied in layers in order to obtain the required thickness. The first layer will be a thin mortar coat applied without fibers and pressed into the wall surface where necessary to insure complete contact with the existing concrete surface. The fiber reinforced spray-up coating shall then be applied in at least four successive layers. Each layer shall be rolled with a device similar to a serrated paint roller having a hard surface in order to densify and smooth the surface. Each successive layer shall be applied before the expiration of the mix set time. All coating application work shall progress downwards from the top of the lock wells in order to minimize damage to the newly applied coatings.

### 9.3 Lift Joints.

The Contractor may fill the chamfers at the existing horizontal construction lift joints with an approved method such as dry pack so that the joints are flush with the lock wall surface before applying the surface coating. It will be acceptable to leave the chamfered lift joints as is, without filling them, and only cover the lift joints with the required thickness coating as long as an acceptable quality of application can be achieved.

### 9.4 Monolith Joints.

The spray-up coating shall be discontinuous across each vertical monolith joint by using a sheetmetal or thin plywood baffle or other approved method to maintain existing joint widths. The Contractor shall submit for approval his intended method of jointing at the monolith joints.

## 10. CURING AND PROTECTION.

### 10.1 Curing.

All application of shotcrete shall be scheduled and completed so that each area of completed application is not subjected to moisture within 36 hours after application. Curing shall be accomplished by leaving the completed coatings exposed to the air and keeping coatings dry from all forms of moisture, including rain, as required by protecting with an approved cover throughout the entire cure period.

#### 10.2 Protection.

Loaded surfaces shall be protected at all times from damage of any kind due to the Contractor's activities throughout the duration of this contract. The Contractor will not be responsible for any damaged coatings caused by boat traffic other than his own, when the lock is in service.

#### 11. REPLACE PAINT STRIPES.

##### 11.1 General.

The 6-foot wide yellow paint stripes which were covered with spray-up coating material shall be repainted in their original locations. Stripes shall be painted with two coats of paint from the top of the parapet wall to tailwater level at elevation 440.0.

##### 11.2 Paint Material.

Paint shall be two-component epoxy-polyamide paint capable of second coat application within 4 hours of first coat application. Physical and chemical properties of paint shall remain unaffected when totally immersed in water 48 hours after application. Color shall be yellow No. 13655 conforming to the listed chip of Fed. Std. 595a, "Colors." Paint available as an "off-the-shelf" item meeting the above requirements is available from Rodda Paint Co., 6932 S.W. Macadam, Portland, OR 97219, telephone: (503)244-7512, Mr. Tom Braden, trade named "Kopon Epoxy," manufacturer's color No. 22949 "Safety Yellow". Paint proposed for use other than "Kopon Epoxy" shall be accompanied with a signed certificate from the paint manufacturer indicating that the paint proposed for use meets all the above specified requirements and that it is a premium grade of paint.

##### 11.3 Surface Preparation.

Paint shall not be applied to spray-up coating material prior to the end of the specified 36-hour cure period. Surfaces to receive paint shall be dry and free from oil, grease, dirt, dust, and other contaminants. Existing epoxy paint on the parapet wall which is loose or flaking shall be removed. Remaining surfaces of existing paint shall be cleaned as recommended by the paint manufacturer.

##### 11.4 Application.

Prior to use paint shall be stored under cover at a temperature of at least 70 degrees F. Where thinning is required to obtain optimum application results, the recommendations of the paint manufacturer as to type and amount of thinner shall be followed. Paint shall be mixed in accordance with the manufacturer's instructions. Each coat shall be applied at a coverage rate not to exceed 300-square feet per gallon. The second coat of paint shall be applied within 4 hours after application of the first coat. Paint shall be applied by spray, brush, or roller. Areas to receive paint shall be masked or other measures satisfactory to the Contracting Officer's Representative shall be taken in order to protect adjacent surfaces from overspray and slobbers and to produce stripes of uniform width with straight vertical lines. Paint applicators and handlers shall wear respirators, rubber gloves, and protective clothing.

#### 12. QUALITY CONTROL.

In accordance with the SPECIAL PROVISIONS, the Contractor shall inspect for compliance with contract requirements including but not limited to shotcrete batching requirements, mix proportions, and consistency at the jobsite, placing, curing, and all other tests and inspections specified or required. Prior to each placement of spray-up coating the Contractor's Quality Control Representative shall certify in writing or by an approved check-out form that surface preparation is in accordance with the plans and specifications. As a minimum, the Contractor shall be required to perform the following:

(1) A minimum of two sand gradation and one sand moisture content test per shift. A recheck sample shall be tested on any test not conforming to specification requirements.



- (2) Mix proportions including sand, cement, admixtures, fibers, latex and water.
- (3) Measure air content of plastic mix after it has been sprayed from the nozzle. Two times per monolith will be required.
- (4) Record fiberglass fiber length.
- (5) Conduct flow and workability tests in accordance with the recommendations of the supplier of the fibers. Two per monolith will be required.
- (6) Measure or accurately estimate and record the amount of rebound for each day's placement (in percent).
- (7) Record and check mix proportions at least once per shift for weigh batching and as recommended by ASTM C 685 for volumetric batching and continuous mixing plants.
- (8) Record ambient temperatures two (2) times per shift at 4-hour intervals.
- (9) Cast shotcrete 3/8-inch x 24-inch x 24-inch specimens in Contractor-furnished molds. Two per monolith will be required.
- (10) Determine final depth of the spray-up coating during application.

The Contractor shall employ personnel qualified to make required tests for quality control and shall report all test results on forms furnished by the Government. A copy of records and tests, as well as the records of corrective action taken, shall be furnished as hereinbefore specified.

\*\*\*\*\*

EXHIBIT 6

REPORT OF TESTS ON FIELD-CAST FIBERGLASS-REINFORCED  
LATEX SPRAY-UP PANELS

<u>Item</u>	<u>Description</u>
1	Letter Report from Division Laboratory
2	Tabulated Laboratory Test Results
3	Load Deflection Graphs of Flexural Tests

ADDRESS REPLY TO  
DIRECTOR  
NOT TO INDIVIDUALS

U. S. ARMY ENGINEER DIVISION, NORTH PACIFIC  
CORPS OF ENGINEERS

NORTH PACIFIC DIVISION MATERIALS LABORATORY  
RT 2, BOX 12A  
TROUTDALE OREGON 97060

NPDEN-GS-L (80-C-710)

22 September 1980

SUBJECT: Lower Monumental Navigation Lock, Report of Tests on Field  
Cast Fiberglass Reinforced Latex Spray-up Panels

District Engineer, Walla Walla  
ATTN: NPWEN-FM

1. Please reference:

- a. Your DA Form 2544 Order No. E85800097 dated 17 July 1980
- b. NPD Form 300 dated 15 April 1980 covering transmittal of fifty-one nominal 1/2" to 3/4" x 24" x 24" fiberglass reinforced latex shotcrete panels (rec'd 4/15/80).

c. Telecon 15 Aug 80 to your Mr. Schrader, NPWEN-FM wherein preliminary results were reported.

2. Attached confirming telephoned information is report of flexural strength, center point deflection, tensile strength, and freeze-thaw durability tests made on the above panels. Included are:

a. Incl 1, Report of Tests on Fiber Reinforced Latex Spray-Up Panels.

b. Incl 2, Graphical Report of Typical Deflection Curves for three Latex Spray-Up Panels.

3. The fifty-one 24 x 24 inch fiberglass reinforced panels were numbered at random when received. Panels ranged from 0.30 to 0.88 inches in thickness with one formed and one rough "as sprayed" face. Due to the time and cost required for milling the sprayed face to a plane surface, the panels were tested as received. Thickness was measured from the formed to the estimated effective cross section of the sprayed face.

EXHIBIT 6  
Item 1  
Page 1 of 3

22 September 1980

SUBJECT: Lower Monumental Navigation Lock, Report of Tests on Field  
Cast Fiberglass Reinforced Latex Spray-up Panels

4. One nominal 2.4 x 12 inch test piece was sawn from each panel for flexural strength and center point deflection tests. Additional test pieces were sawn from nine panels for duplicate tests. Flexural strength was determined by third point loading, simple span = 10.0 inches. A total of twenty-nine panels were tested with the formed face in tension and thirty-one with the sprayed face in tension. Deflection was measured at the center point. Freeze-thaw and tensile strength tests were made on six each nominal 2.4 x 6 inch test specimens from panels Nos. 4, 8, 12, 16, 20, 24, 28, 32, 36, 40, 44, and 48. Freeze-thaw specimens were soaked 48 hours prior to test. Tensile test specimens were loaded in direct tension by use of chain coupled clamps. Tensile strength ranged from 720 to 1300 psi, with an average strength of 950 psi. The freeze-thaw test specimens had an average weight gain of 0.5 percent at 300 cycles. It is believed the weight gain was due to additional water absorbed during over the 25 days of test. Apparently this weight gain was greater than the slight loss due to the freezing-thawing erosion.

5. Average flexural strength of the specimens tested with the formed and "as sprayed" faces in tension was 2250 and 3500 psi, respectively. Results of duplicate tests made on specimens from nine panels confirmed flexural strength was effected by orientation of the panel. Average flexural strength for the nine sets of test pieces, from the same panels, with the formed faces in tension was 1890 psi versus 3360 psi with the "sprayed" face in tension. In eight of the nine test sets the sprayed face had a significantly higher flexural strength with one set approximately equal. Detailed results are shown in Inclosure No. 1. Additional tests were made on pieces sawn from three panels to (1) determine the reliability of the test equipment and method and, (2) to determine the consistency of the panels. Results were as follows:

Panel No.	Flexural Strength, psi			
	#1	#2	#3	Avg
6	1800	2140		1970
15	3400	3530	1710	2880
34	2360	2660	2580	2530

Results indicate the panels are generally consistent in quality and the test results are reproducible. The reason for the difference in flexural strength due to the orientation of the sprayed and formed faces is not definitely known. The sprayed faces were quite rough with a surface relief of approximately 1/4-inch. A combination of fiber orientation and localized crushing under the loading head and supports may have been a contributing factor.

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SUBJECT: Lower Monumental Navigation Lock, Report of Tests on Field  
Cast Fiberglass Reinforced Latex Spray-up Panels

6. Analysis of the deflection data indicates the flexural beams had little residual strength capacity after the ultimate strength was obtained. Deflection readings were difficult to obtain once the ultimate strength was reached as the beam load capacity generally fell rapidly to near zero or the beam failed completely. The deflection curves shown in Inclosure 2 are typical of the flexural beams tested.

8. This completes all work requested

Incl (dupe)  
as

  
G.E. EORGE  
Director

LOWER MONUMENTAL  
Report of Tests on Fiber Reinforced  
Latex Spray-Up Panels

22 SEP 67

Panel No.	Identification	Elevation	Date Placed	Panel Depth, Inches	Flexural <sup>1/</sup>		Deflection <sup>2/</sup> Ultimate Load, Inches	Tensile <sup>3/</sup> Strength, psi	Freeze-thaw Loss, % Wt. (1,000 cycles)
					Strength, psi Tensile Face Formed	Shot			
4	S.M. Latex Test	-	-	0.82	3790		0.35		+ 0.9
23	Mono. 6	542-548	3/16	0.35		2920	0.60		
1	Mono. 25	540-555	3/17	0.31	2530	5240	0.17		
10	Mono. 26	545-552	3/17	0.60	1050		0.16	770	
11	Mono. 7	545-550	3/18	0.39	2350	1610	0.60		
29	Mono. 19	530-515	3/19	0.42	2180		0.23		
15	Mono. 16	525-530	3/20	0.30	4270		0.73		
19	Mono. 17	520-525	3/21	0.46	1980		0.40		
28	Mono. 23	515-520	3/22	0.65	2120		0.32		+ 0.8
27	Mono. 22	505-510	3/23	0.30	4340		0.48		
26	Mono. 11	495-500	3/24	0.58		1480	0.09		
13	Mono. 15	500-505	3/24	0.47	2880	4060	0.51		
13	Mono. 12	495-500	3/25	0.50		3800	0.13		
22	Mono. 15	490-495	3/25	0.50		3750	0.38		
18	Mono. 18	495-500	3/25	0.47	1820		0.13		
32	Mono. 9	485-490	3/26	0.59	2920		0.31	930	
43	Mono. 9	480-485	3/27	0.41		5610	0.23		
30	Mono. 10	485-490	3/27	0.53		3650	0.32		
11	Mono. 17	485-490	3/27	0.65	1090	3610	0.25		
25	Mono. 26	455-460	3/27	0.79	1210		0.18		
6	Mono. 1	465-460	3/28	0.47	1970	1510	0.23		
11	Mono. 11	465-470	3/28	0.58		4000	0.48		
3	Mono. 15	465-470	3/28	0.51		3880	0.52		
9	Mono. 22	465-470	3/28	0.48	1770	1790	0.15		
18	Mono. 4	455-460	3/29	0.63		4730	0.32		
2	"	460-465	"	"		3710	0.45		
14	"	465-470	"	0.44		4170	0.55		
7	"	455-460	"	0.64	1430		0.08		
8	Mono. 3	460-465	3/30	0.53	1410		0.16	880	
5	"	450-455	"	0.81	1550		0.18		
1	"	455-460	"	0.25		4610	0.47		
16	Mono. 5	445-450	3/31	0.50		2560	0.51	910	
12	"	445-450	"	0.60	1470	4170	0.15		+ 0.1
16	"	"	"	0.44	1750	2720	0.47	1000	
10	"	"	"	0.58		4240	0.17		
13	"	"	"	0.47		3500	0.49		
17	"	"	"	0.88	2150		0.25		
51	Mono. 7	435-440	4/1	0.36	1860		0.41		
36	"	"	"	0.44		4060	0.33		+ 0.5
27	"	440-445	"	0.60		1500	0.21		
50	"	435-440	"	0.47	2200		0.39		
42	"	"	"	0.62		2640	0.21		
41	"	"	"	0.56	2890		-		
19	"	450-455	"	0.53	1790		0.29		
17	"	435-440	"	0.47		4190	0.45		
28	"	"	"	0.28	2620		0.18		
19	"	450-455	"	0.16		3470	0.41	940	
20	"	"	"	0.74	1170	3350	0.24		+ 0.1
45	"	435-440	"	0.70		3160	0.51		
24	"	"	"	0.26	4820		0.60		+ 0.0
56	"	440-445	"	0.47		2620	0.22		
Number Tests					29	31	50	6	6
Average, psi					2250	3500	0.35	950	+ 0.5
Range, psi					1050 to 4820	1480 to 5240	0.09 to 0.73	720 to 1400	0.0 to 0.9

NOTE: 1/ - On nominal 2.4" x 1" pieces, third point loading, 10.0" span.

2/ - Deflection at center point of flexural strength test panels.

3/ - On nominal 2.4" x 8" panels.

NO. 1406

EXHIBIT 6  
Item 2  
Page 1 of 1

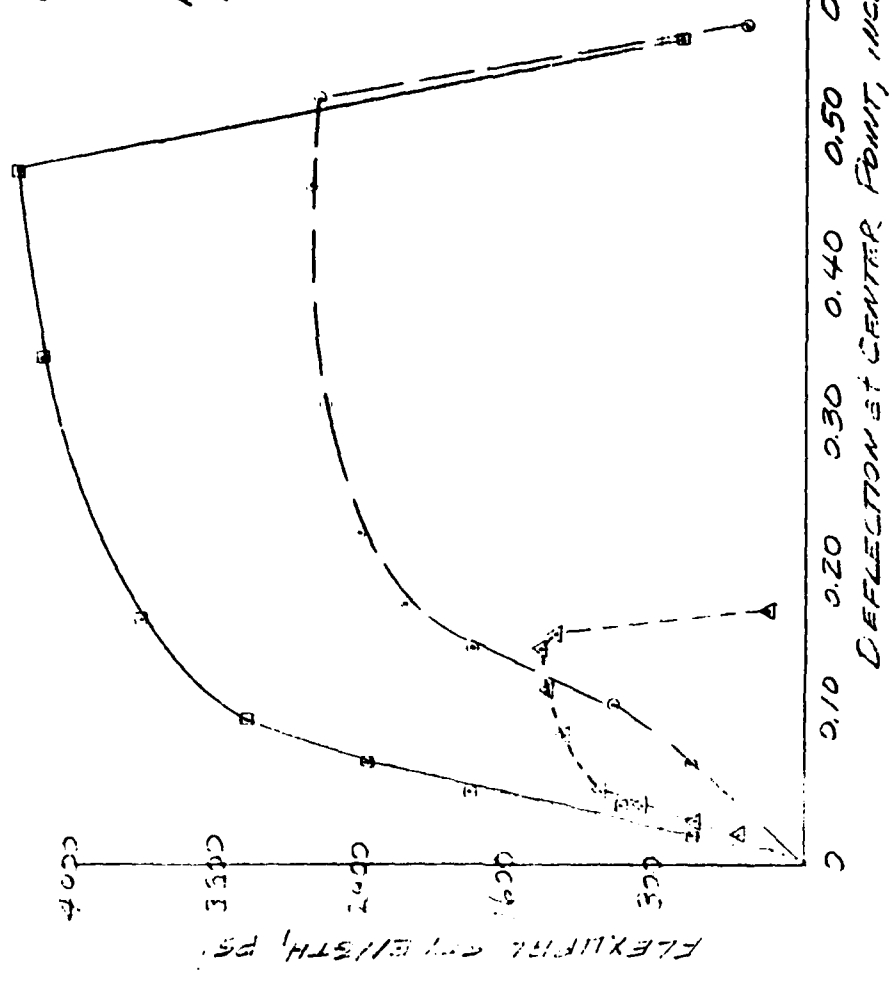
22 SEP 1980

NPDEN-55-L (80-C-710)

EXHIBIT 6  
Item 3  
Page 1 of 1

DEFLECTION VERSUS  
LOAD  
NOMINAL 1/2"-3/4" x 2.4"x  
10" PANELS FROM  
FIBER GLASS REINFORCED  
LATEX SPRAY UP PANELS

PANEL  
○ NO. 4  
□ NO. 27  
△ NO. 12



NPDL  
AUG 80

# LOWER SNAKE RIVER PROJECT

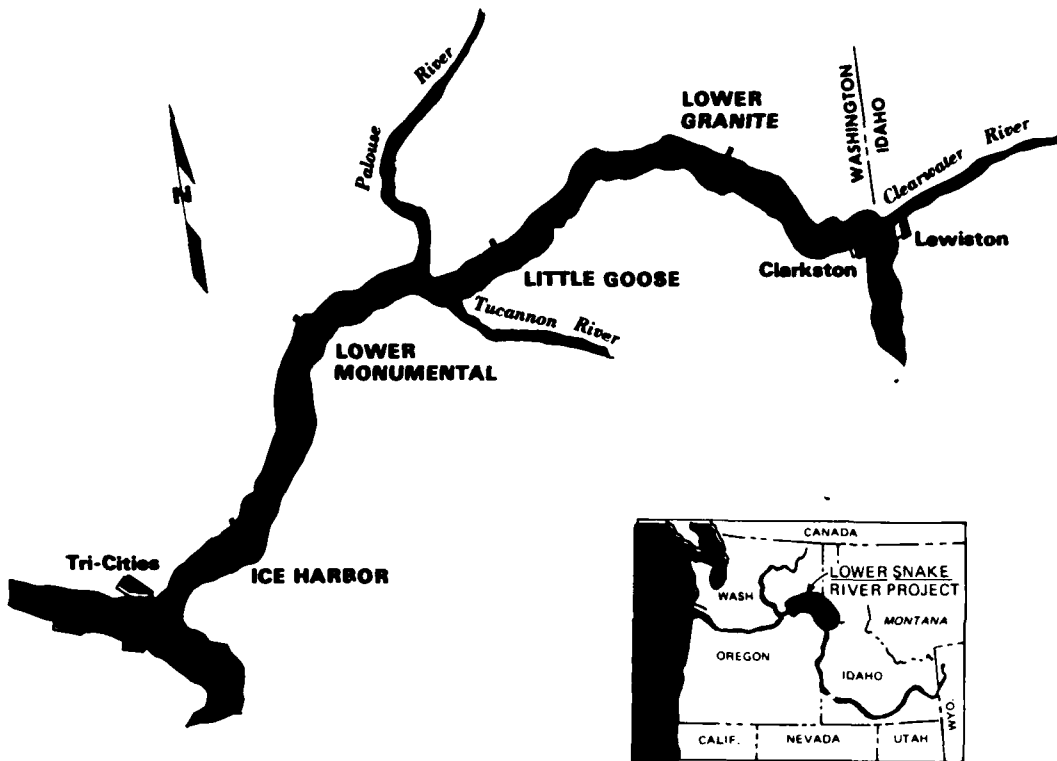
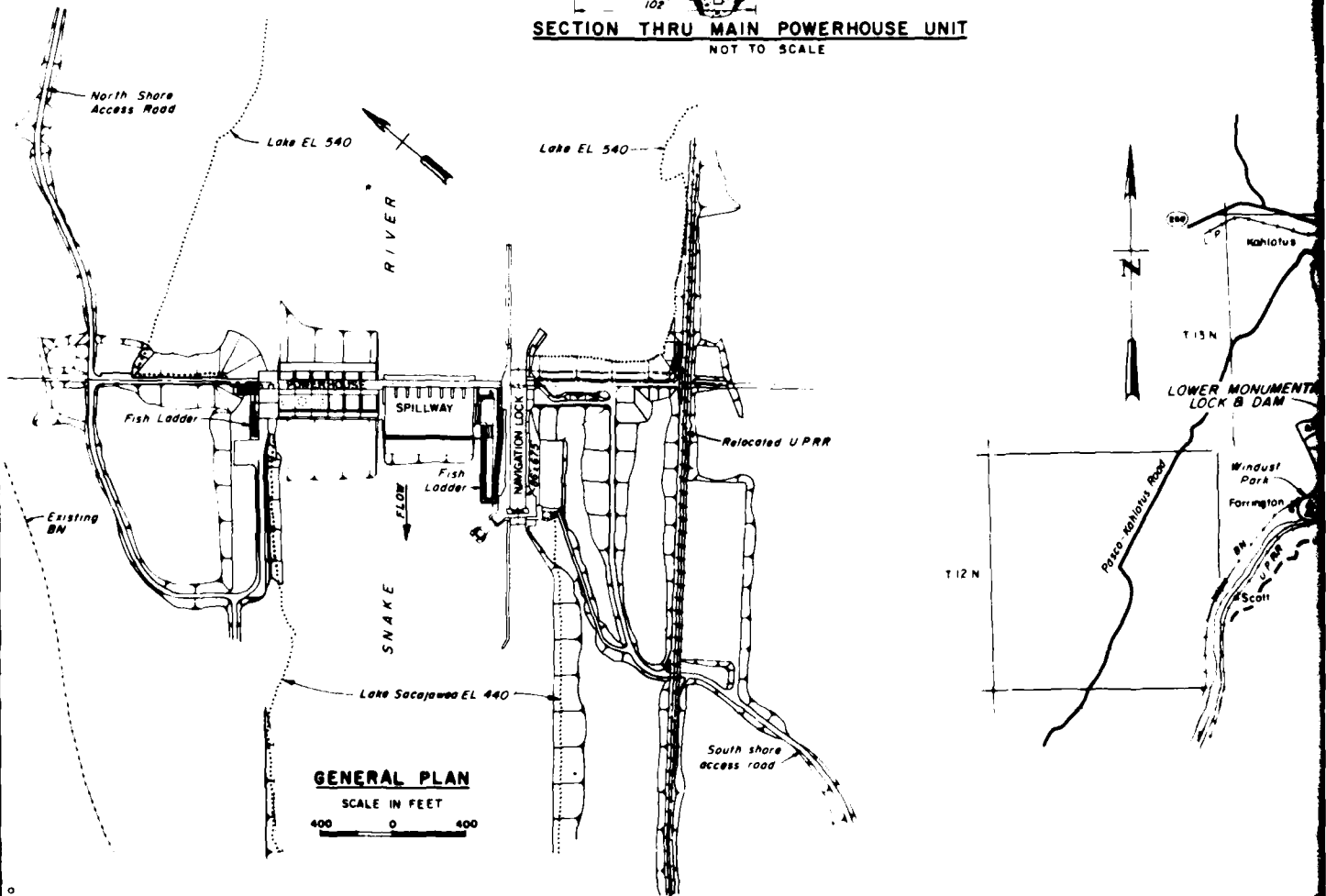
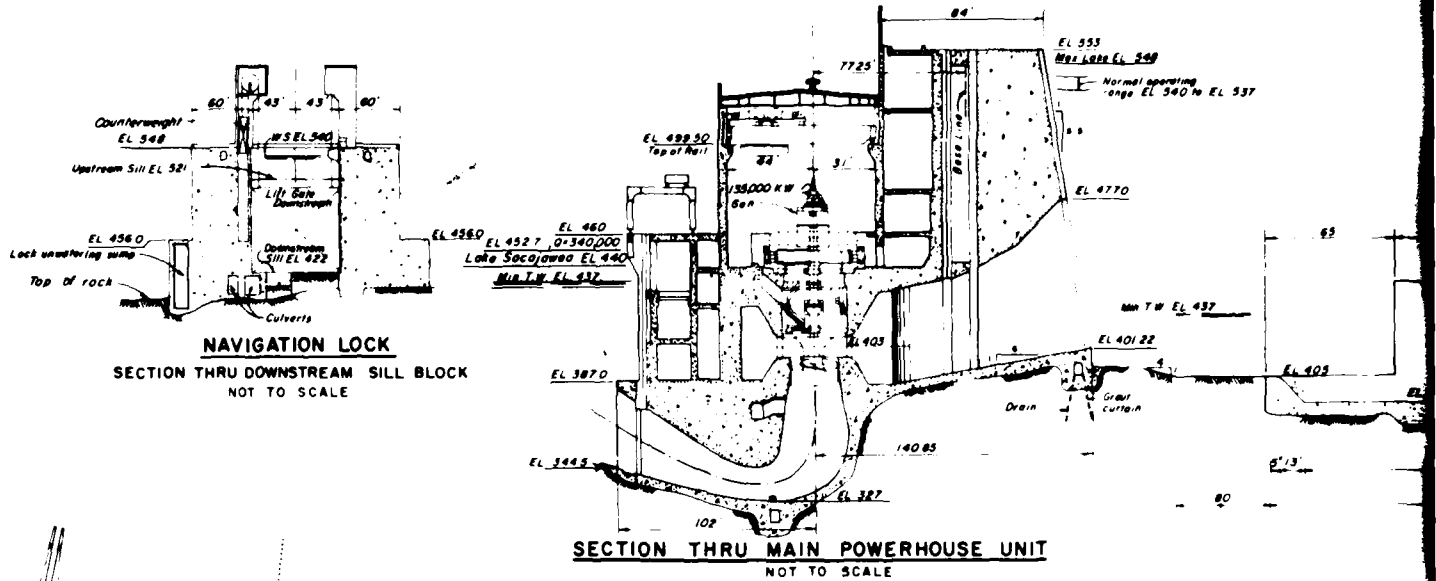


PLATE 1



CORPS OF ENGINEERS



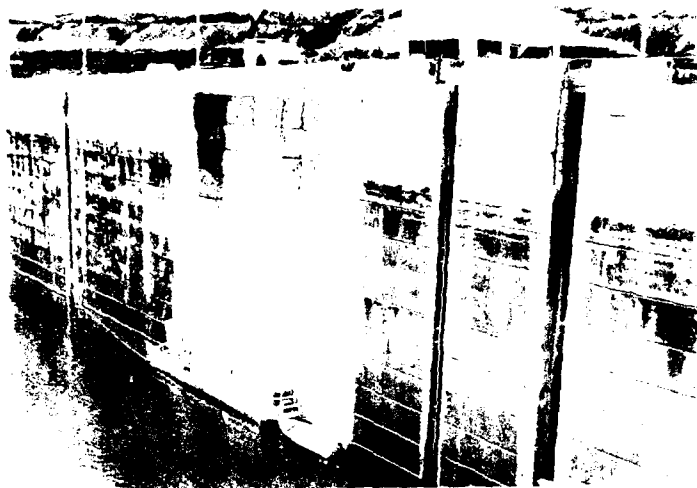


**Snake River**  
OREGON, WASHINGTON AND IDAHO  
**LOWER MONUMENTAL LOCK AND DAM**  
U S ARMY ENGINEER DISTRICT, WALLA WALLA  
REVISED TO 30 JUNE 1974



LOWER MONUMENTAL LOCK AND DAM

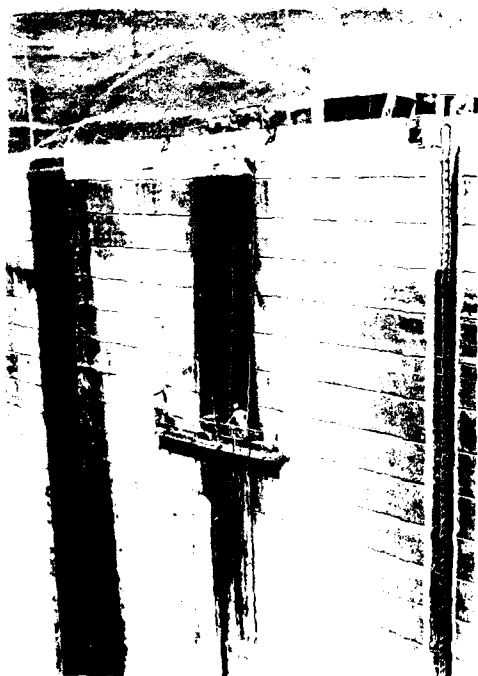
PLATE 3



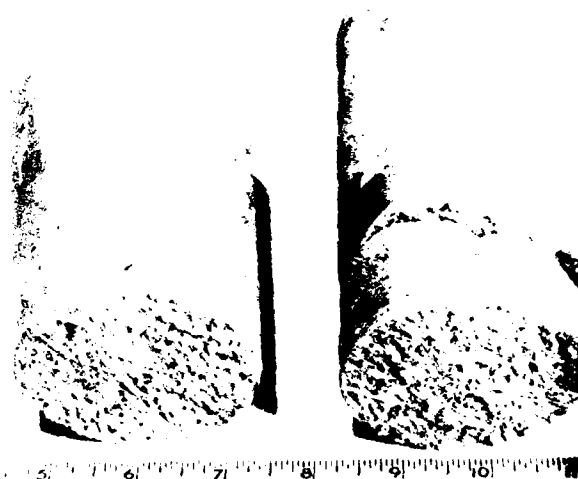
APPLYING ONE OF THE TRIAL SURFACE COATINGS TO MONOLITH 9 FROM A FLOATING PLATFORM.



APPLICATION OF THE SPRAY-UP MORTAR AND FIBER FIBERS FROM THE "NOZZLE" AND "CUTTER HEAD" DURING THE TRIAL COATING OPERATION. ROLLING OF THE COATING IS BEING DONE IMMEDIATELY BEHIND THE SPRAY APPLICATION.



APPLICATION OF ONE OF THE 10 FOOT WIDE TRIAL COATINGS FROM A CROWDED HANGING SCAFFOLD.



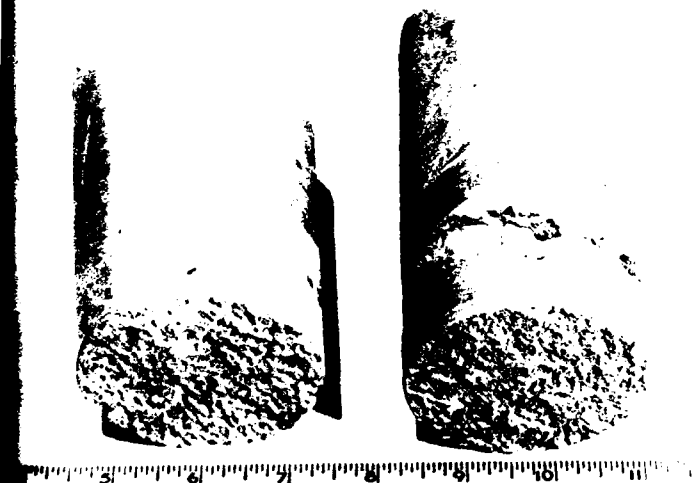
TWO TYPICAL CORES TAKEN FROM THE LOCK WALL THROUGH THE TRIAL COATING. THE CORE ON THE LEFT SHOWS EXCELLENT BOND OF THE COATING TO THE CONCRETE. THE CORE ON THE RIGHT FAILED AT THE INTERFACE ALONG UNSOUND MATERIALS NOT PRE-CLEANED FROM THE SURFACE BEFORE APPLICATION OF THE COATING.



APPLICATION OF THE SPRAY-UP MORTAR AND FIBERGLASS FIBERS FROM THE "NOZZLE" AND "CUTTER HEAD" DURING THE TRIAL COATING OPERATION. ROLLING OF THE COATING IS BEING DONE IMMEDIATELY BEHIND THE SPRAY APPLICATION.

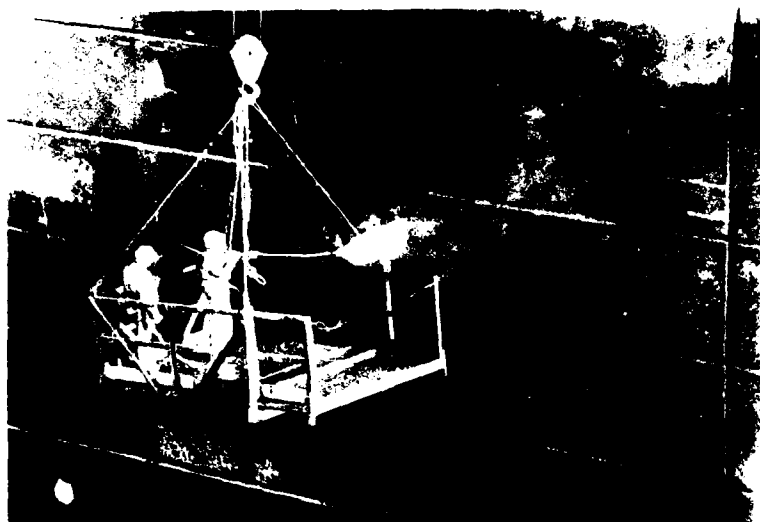


APPEARANCE OF THE LOCK WALL 9 MONTHS AFTER APPLICATION OF THE TOTAL COATING VISIBLE IN THE FOREGROUND. THE UNCOATED WALL IS IN THE BACKGROUND.



TWO TYPICAL CORES TAKEN FROM THE LOCK WALL THROUGH THE TRIAL COATING. THE CORE ON THE LEFT SHOWS EXCELLENT BOND OF THE COATING TO THE BASE CONCRETE. THE CORE ON THE RIGHT FAILED AT THE INTERFACE ALONG UNSOUND MATERIALS NOT PROPERLY CLEANED FROM THE SURFACE BEFORE APPLICATION OF THE COATING.

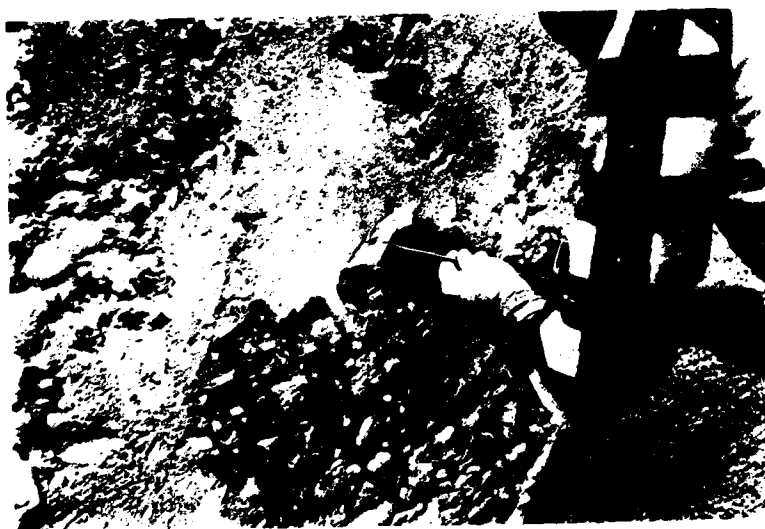
# PHOTOGRAPHS OF THE TRIAL COATING PLATE 4



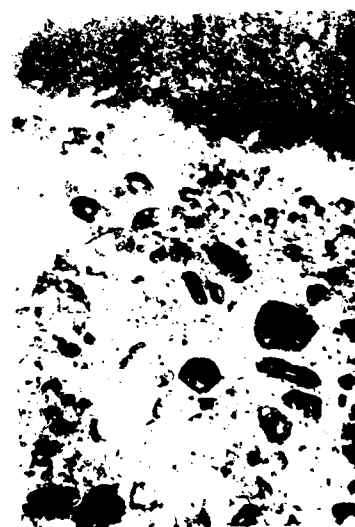
TRIAL SURFACE CLEARING WAS DONE PRIOR TO PREPARATION OF BIDDING DOCUMENTS TO CONFIRM WHAT DEGREE OF CLEARING WAS NECESSARY AND COULD PRACTICALLY BE ACCOMPLISHED WITH VARIOUS PIECES OF EQUIPMENT IN THE FIELD.



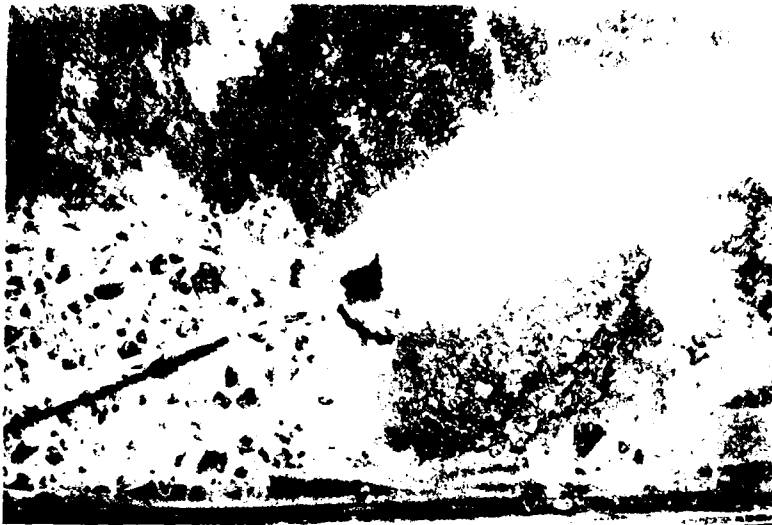
A HIGH PRESSURE WATER JET 6500 PSI FLAKES OFF THE O



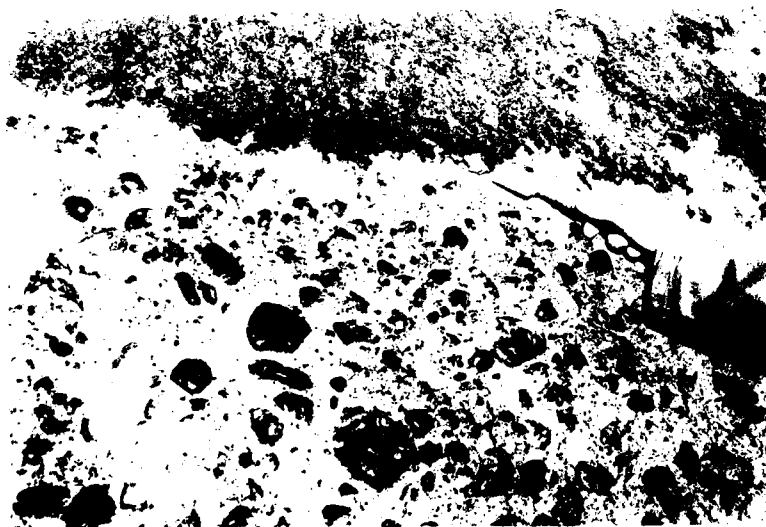
TWO EXAMPLES OF HOW EASILY THE UNSOUND 1/4 INCH (APPROX) OF SURFACE MORTAR WOULD NOT ALREADY SCALED AWAY.



PHOTOGRAPHS OF SURFA



A HIGH PRESSURE WATER JET OPERATING HERE AT ABOUT 6500 PSI FLAKES OFF THE OUTER LAYER OF UNSOUND MORTAR.



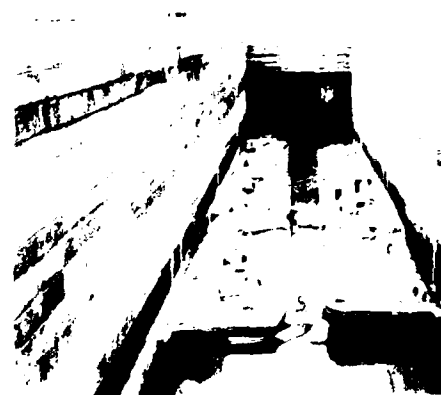
OF SURFACE MORTAR WOULD FLAKE OFF WHERE IT HAD

PHOTOGRAPHS OF SURFACE CLEANING TECHNIQUES

PLATE 5



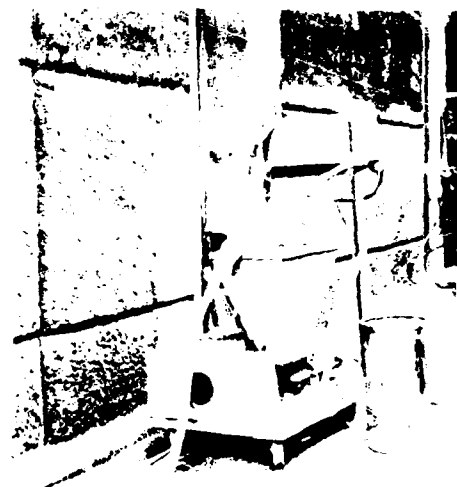
WORKING FROM BARGES TO APPLY THE LOCK WALL COATING NEAR THE UPPER LIFTS.



LOCK WALL ABOUT 75% COATED WITH THE WORK BARGES.



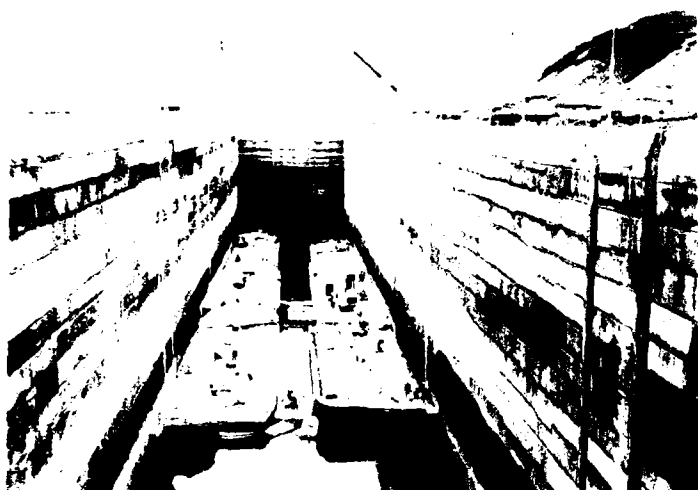
APPLYING THE MORTAR SIMULTANEOUSLY WITH THE FIBERGLASS FIBERS IN AN AREA OF MINIMAL SCALING NEAR THE TOP OF THE LOCK.



ONE OF THE FOUR SPRAY-UP UNITS FROM THE MIXER IN THE TUB AND PUMP. IT IS PUMPED THROUGH THE TUB WHERE IT IS ATOMIZED AND SPRAYED SIMULTANEOUSLY CUTTING THE FIBER OVERHEAD STRAND AND BLOWING

PHOTOGRAPHS OF CONTRACT RE





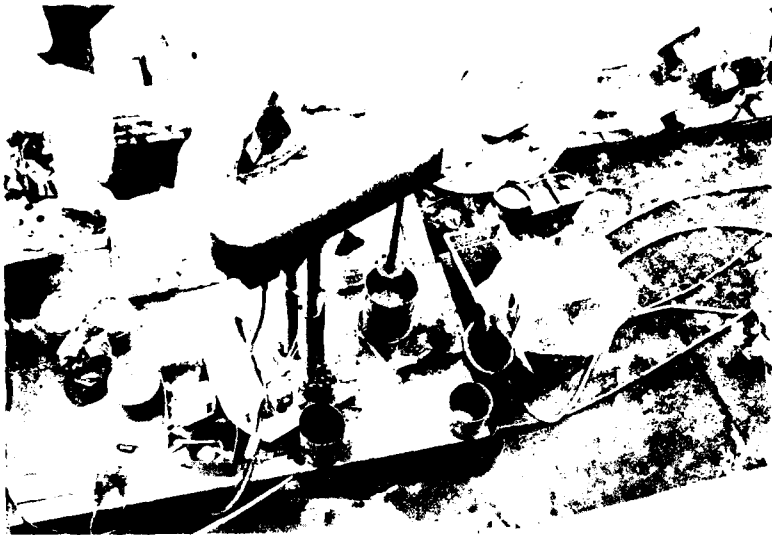
LOCK WALL ABOUT 75% COATED AND GOING DOWN WITH THE WORK BARGES.



ONE OF THE FOUR SPRAY-UP UNITS. MORTAR IS BROUGHT FROM THE MIXER IN THE TUB AND DUMPED INTO THE GROUT PUMP. IT IS PUMPED THROUGH THE HOSE TO THE NOZZLE WHERE IT IS ATOMIZED AND SPRAYED ONTO THE WALL WHILE SIMULTANEOUSLY CUTTING THE FIBERS FROM A CONTINUOUS OVERHEAD STRAND AND BLOWING THEM ONTO THE WALL.

PHOTOGRAPHS OF CONTRACT REPAIR OPERATIONS (I)

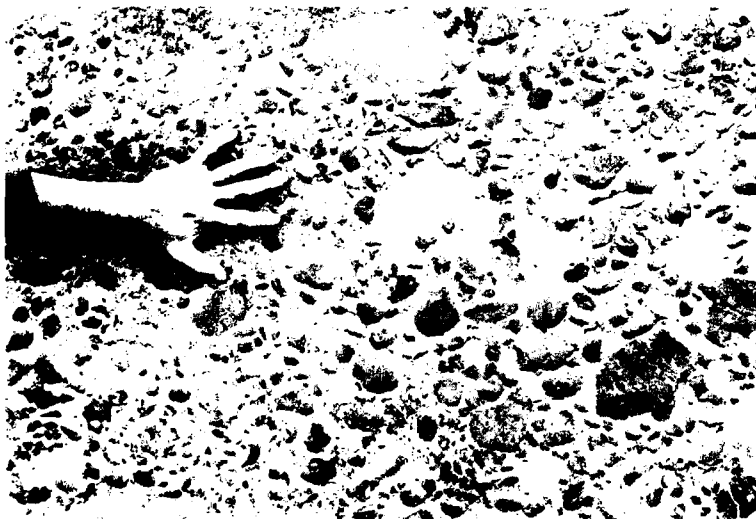
PLATE 6



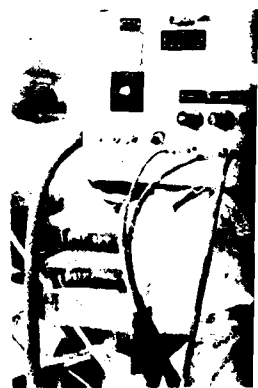
HIGH SHEAR MORTAR MIXER. THE GROUT PUMP TO THE RIGHT HAS THE CONTROLS COVERED WITH POLYETHYLENE SHEET. CEMENT IS STOCKPILED IN BACK.



TIMING THE MIX  
MORTAR MIXER

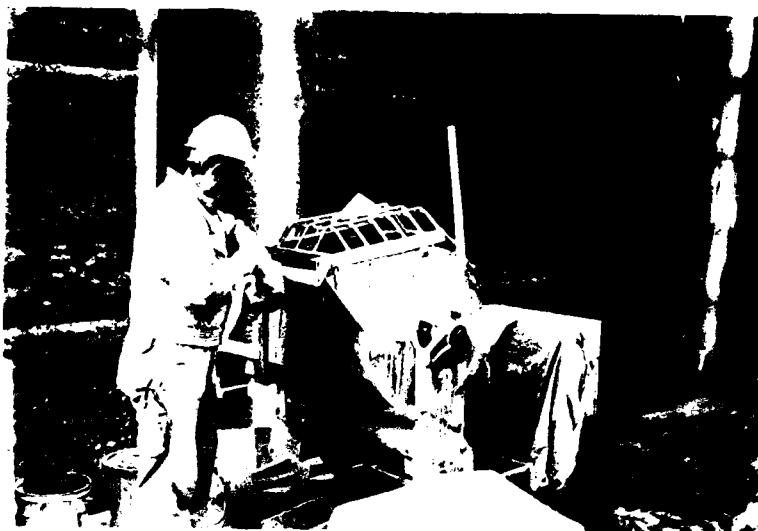


WALL SURFACE AFTER ACCEPTABLE SURFACE PREPARATION  
IN THE LOWER LIFTS.

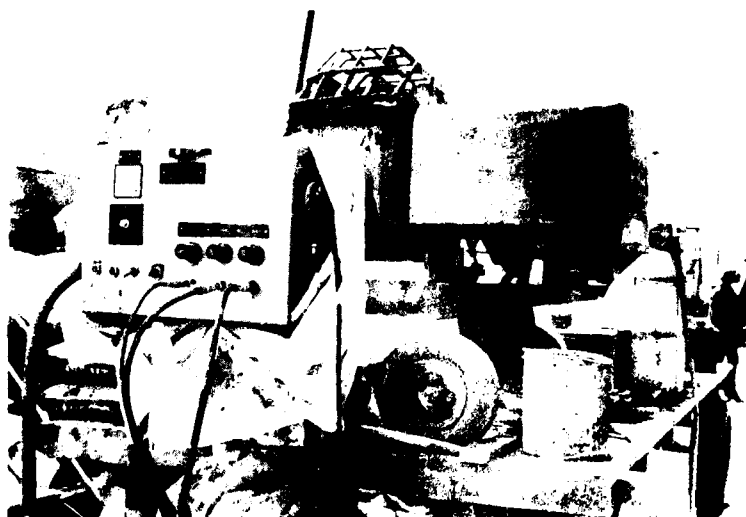


MORTAR MIXI

PHOTOGRAPHS OF CON



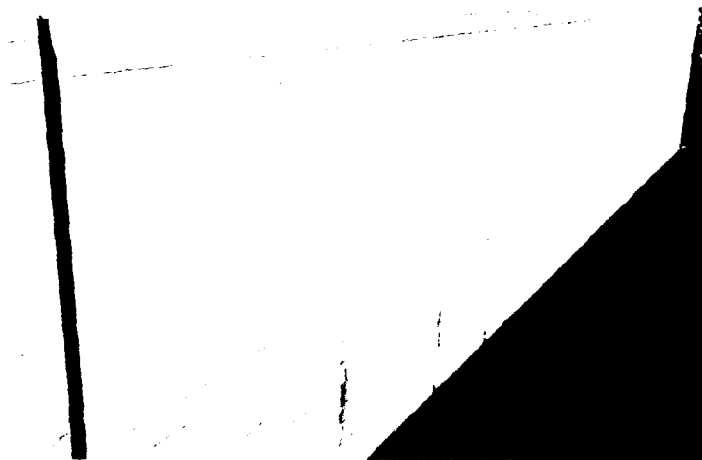
**TIMING THE MIX DURATION IN A CONVENTIONAL  
MORTAR MIXER.**



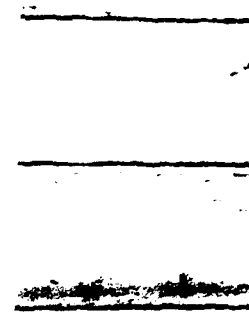
**MORTAR MIXER AND PUMP CONTROL BOARD.**

**PHOTOGRAPHS OF CONTRACT REPAIR OPERATIONS (II)**

**PLATE 7**



APPEARANCE OF THE NORTH LOCK WALL AFTER ABOUT 6 MONTHS OF SERVICE.



CONDITION OF THE IMPACT MARKS W COATING.

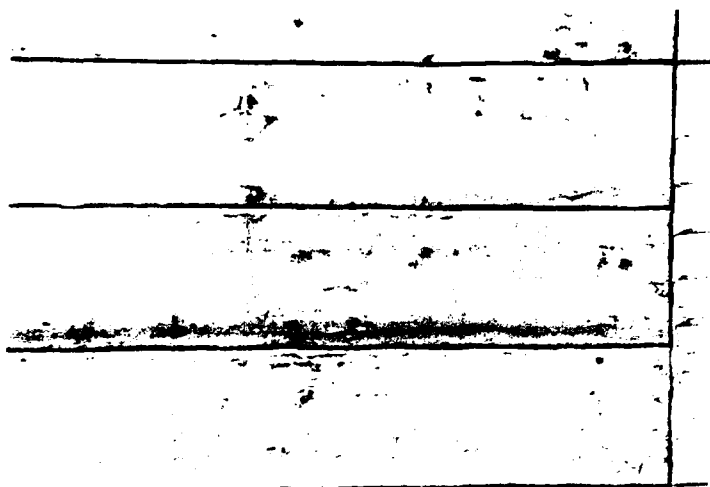


APPEARANCE OF THE WALL COATING IN THE UPPER LIFTS WHICH HAD MINIMAL DETERIORATION.

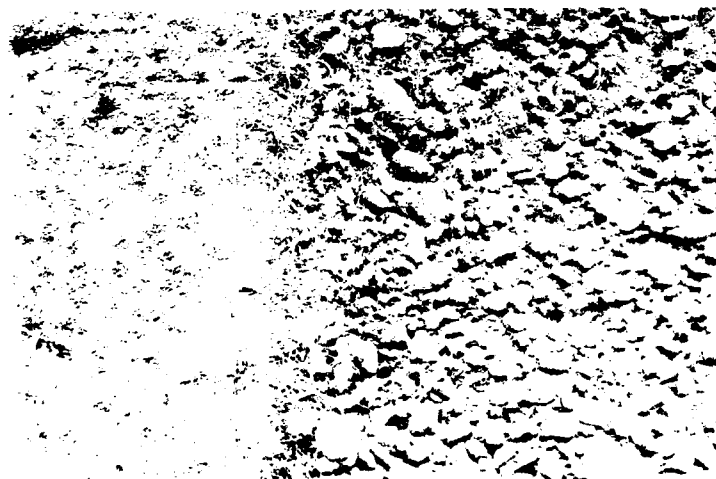


APPEARANCE OF COVERS VERY RC CONCRETE SIMILA

PHOTOGRAPHS OF CONT



CONDITION OF THE LOCK WALL SHOWING RUB AND  
IMPACT MARKS WHERE BARGES HAVE HIT THE WALL  
COATING.



APPEARANCE OF THE COATING TO THE LEFT WHERE IT  
COVERS VERY ROUGH AND SEVERELY DETERIORATED  
CONCRETE SIMILAR TO THAT VISIBLE TO THE RIGHT.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Schrader, Ernest K.

Deterioration and repair of concrete in the Lower Monumental Navigation Lock Wall : final report / by Ernest K. Schrader (U.S. Army Engineer District, Walla Walla). -- Vicksburg, Miss. : U.S. Army Engineer Waterways Experiment Station ; Springfield, Va. : available from NTIS, [1981].

113 p. in various pagings, 8 leaves of plates (some folded) : ill. ; 27 cm. -- (Miscellaneous paper / U.S. Army Engineer Waterways Experiment Station ; SL-81-9)

Cover title.

"June 1981."

"Prepared for Office, Chief of Engineers, U.S. Army under CWIS 31553."

"Monitored by Structures Laboratory, U.S. Army Engineer Waterways Experiment Station."

1. Concrete dams. 2. Locks (Hydraulic engineering).  
3. Lower Monumental Lock and Dam (Wash.) 4. Navigation.

Schrader, Ernest K.

Deterioration and repair of concrete in the Lower : ... 1981.  
(Card 2)

I. United States. Army. Corps of Engineers. Office of the Chief of Engineers. II. United States. Army. Corps of Engineers. Walla Walla District. III. U.S. Army Engineer Waterways Experiment Station. Structures Laboratory. IV. Title V. Series: Miscellaneous paper (U.S. Army Engineer Waterways Experiment Station) ; SL-81-9. TA7.W34m no.SL-81-9

